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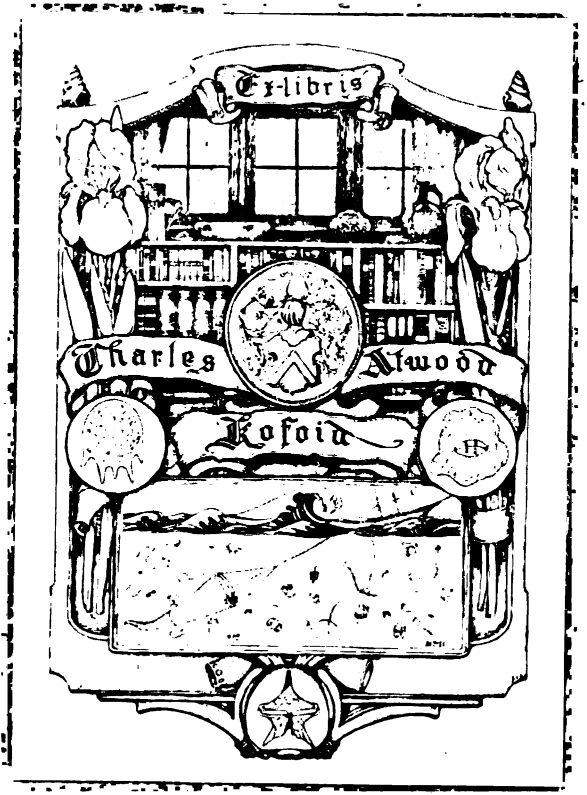
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[From The Johns Hopkins Hospital Bulletin, Vol. XXI. No. 229, April, 1910.]

ON THE CUTANEOUS DISTRIBUTION OF THE SUPERFICIAL RAMUS OF THE RADIAL NERVE AND ITS COMPENSATORY EXTENSION.

By Irving Hardesty,
Department of Anatomy, University of California.

Total absence of function of the branches of two of the [102] three nerves distributed to the lower forearm and hand produced with destruction of the tendons of the forearm, but leaving the hand intact, seems of comparatively rare occurrence. More than a year ago Dr. Harry M. Sherman, of the Department of Surgery of the University of California, submitted to me a patient of his who had suffered an injury of the ulnar side of the forearm, resulting in the destruction of both the ulnar and median nerves, and later he kindly allowed me numerous opportunities to examine the case. The study resulted in a few observations which may be of general interest. These observations include (1) corroboration of the position and extent of the cutaneous area of the hand and wrist supplied by the radial nerve; (2) proof of the retardation of growth and regeneration by scar tissue; (3) retardation of growth of peripheral nerve fibers by impaired nutrition of the tissues to be innervated, and (4) the tendency on the part of the intact nerve toward a compensatory extension of its area into domains not originally occupied by it, but which have lost their usual innervation.

Surgical History of the Case.

Dr. Sherman supplied the following history of the case:

F. L., æt. 50 yrs., a miner.

In August, 1905, he had his left forearm caught between cogwheels and suffered a severe crush with fracture of the ulna and

[102] laceration of the flexor tendons on the middle and ulnar side of the forearm. Both the median and the ulnar nerves were severed and implicated in the slough.

Healing left a sound ulnar bone with a scar, depressing the skin surface and attached to the bone, occupying the middle and ulnar regions of the lower half of the forearm.

Patient was unable to use the flexor muscles of the forearm except the radial flexors of the carpus. He had slight control over the thumb. There was no sensation in the fingers except the radial side of the index finger. There was sensation in the thumb. The palm of the hand had sensation external to a line drawn between the first and second metacarpal bones. There was no sensation on the ulnar side of the forearm. On the back of the hand the anesthesia and the sensation corresponded to the ulna and radial nerve distributions respectively.

An attempt was made to unite the median nerve to the radial by reflecting a flap from the side of the median and carrying it over to and inserting it into the radial. In doing this the integrity of the radial was very carefully preserved, for the result of the procedure was so problematic that it seemed unwise to jeopardize the radial conductivity. At the same time the contact was adequately made. An attempt was made to reunite the severed tendons. This was found impracticable because of the union of the scar to the ulna, so the scar was dissected out and a flap of skin was turned up from the chest, the arm brought up to it and the flap sutured to the forearm. When it had united, the flap and the arm were detached from the chest. At a later date and after all wounds in the forearm had healed, a silk tendon was put into the flexor muscles of the forearm and carried underneath the flap and stitched to the cut tendons just below the wrist. It was found impracticable to isolate individual muscles and individual tendons and so a common flexor tendon for all of the fingers was arranged for. This process took a long while and when all of the wounds had healed, the man had recovered flexion of his wrist, but had not individual flexion of the fingers or flexion of the fingers collectively. There was no evidence that any function was permitted by the union between the median and the radial nerves.

When Dr. Sherman submitted the patient to me, more than two years had elapsed since the accident resulting in the injury, and my first examination was made about nine months after the last operation, the grafting on of the skin flap from the chest, had been performed. The wound had completely healed, but the skin and general condition of the hand yet indicated considerable impairment of the blood supply due, in part, to incomplete restoration of the supply destroyed in the wound, and in part to loss of nervous vascular control. [102]

As seen in the history, the original injury, produced by the crushing and tearing of the forearm by the cogwheels, was so serious as to produce far more complicated disturbances than result from simple accidental severing of the ulnar and median nerves. Not only the nerves but the flexor tendons and portions of the muscles of the ulnar side and the median or front side of the forearm were lacerated by the cogs. In addition, there was the considerable sloughing accompanying the first healing and the formation of a large amount of scar tissue which involved the frayed ends of the nerves and tendons, and which made it necessary for Dr. Sherman to remove the scar tissue and graft on a flap of skin from the chest. This necessity resulted in further confusion due to the actual loss of original tissue and to the transplanting of strange skin in the area affected.

Thus, the general symptoms were more extensive than are described as resulting from section of the nerves alone. The [103] characteristic claw-hand had developed, as was to be expected from loss of the ulnar and median nerves, but, due to destruction of the flexor tendons, the metacarpals and first phalanges of all the digits showed more over-extension than usually described from injury to either or both of the nerves alone, and the second and third phalanges seemed less flexed. There was but a slight ability to control the thumb. Its terminal phalanx could be imperfectly flexed and extended, and the thumb could be slightly adducted, but its metacarpus and first phalanx maintained a general position of extension and abduction. There was a total inability to spread out the remaining digits or to further flex and extend them, and the power of pronation was lost.

Owing to the confusion resulting from the destruction of the tendons and injury to the muscles and the very imperfect muscular activity possible even in the event of complete restoration of the nerve supply to the muscles, all attempts to determine evidences of growth and regeneration of nerve fibers to the muscles were discarded. It was decided to confine attention solely to cutaneous distribution proper. Sensations

[108] manifest in the tela subcutanea and fascia appeared too vague and indefinite along the margins of the anesthetic areas to be satisfactorily located and delineated.

The ordinary method for determining the extent of cutaneous sensations was pursued in the following way:

At intervals varying from two weeks to two months the patient was taken into a quiet and warm room, his arm bared to the elbow and extended on a small work-table and upon a cushion of warm towels, and covered with warm towels. Owing to the impaired circulation of the hand and forearm it was deemed of prime importance that, throughout each period of examination, the skin be maintained as uniformly as possible at or slightly above normal blood temperature. Especial care was taken that the patient's position, seated at the table, was as comfortable as possible. The patient was then blindfolded. An esthesiometer of the model devised by Max von Frey was used for all the studies, with the bristle extended 7 mm. Beginning well within the known anesthetic area, the skin was pricked vertically at intervals of 2 to 3 mm. in a line toward the area known to be sensitive. The pressure exerted in pricking the skin was controlled by continuing it in each instance till the bristle just began to bend, and then suddenly removing it. The patient was directed to indicate by the word "yes" his first perception of cutaneous sensation, and the prickings were made about 2 seconds apart to give time for discrimination. Upon the sign "yes" being given, an assistant, who likewise watched the point of the bristle, made a small dot of India ink upon the spot stimulated, using a fine-pointed camel's-hair brush. The lines of prickings, passing from the anesthetic toward esthetic regions, were made from 5 to 10 mm. apart, depending upon the locality. Whenever there was doubt as to the point at which sensation began, a line of prickings was repeated. When the ink dots were made at sufficiently frequent intervals, indicating points in the margin of the sensitive area, the dots were carefully joined into a solid line with the brush point carrying India ink. Thus a continuous black line was obtained defining the boundary between the areas.

The hand and forearm were next photographed in three or four positions. The dorsal and palmar surfaces and the ulnar [108] aspect were always taken, and sometimes both the radial and ulnar aspects. Attempt was made to make all the photographs to scale. Tracings were made from these photographs of the hand and forearm, and the ink line upon them, which latter always came out sharply. Figs. 1 to 5 are reproductions of 12 of these tracings, with the sensitive area filled in with stippling.

The fact is appreciated that determinations of the boundaries of sensitive cutaneous areas are usually untrustworthy as to accuracy, due to the vagueness of the sensations along the border line, and especially to the varying mental equations of both the patient and the operator. Every precaution was taken to guard as much as possible against inaccuracies. The hand and forearm were kept warmed during each examination; the examinations were made under similar conditions of quiet and room temperature. To guard against errors arising from fatigue, the blinder was removed at intervals of about 15 minutes and the patient was induced to turn his attention to other things. During these intervals, the warm towels, upon which the arm and hand had rested and with which they were partly covered, were renewed. Fortunately, the patient was a man of remarkably unexcitable disposition and understood very little of the object of the investigation. His attention was confined to giving the sign as directed, and only upon perception of positive pricking sensations from the skin. Sensations of pressure by the bristle were often mentioned, but disregarded as subcutaneous rather than cutaneous.

Owing to the well-known fact, noted by Tillmans,[1] Thorburn and Williamson,[2] and others, that adjacent territories of nerves overlap each other through the interextension of the collateral and terminal twigs of the nerves, it is realized that the territories of different nerves rarely appear sharply defined. In this case, however, all the nerve twigs for the skin of the hand were totally destroyed except the twigs of the intact superficial ramus of the radial nerve, and thus all sensations

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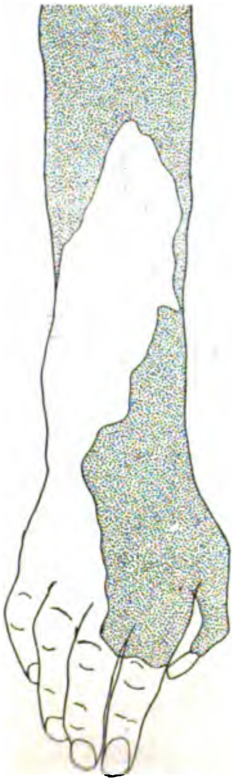
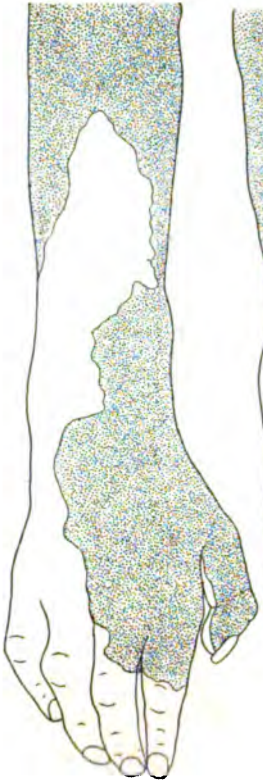
[1] Tillmans: Archiv für Klinische Chirurgie, 1882, Bd. 27, p. 1.

[2] Thorburn and Williamson: Encyclopedia Medica, 1901, Vol. 8, p. 282.

Oct. 30, '07.
Fig. 1a.



Nov. 26, '07.
Fig. 2a.



Jan. 26, '08.
Fig. 3a.

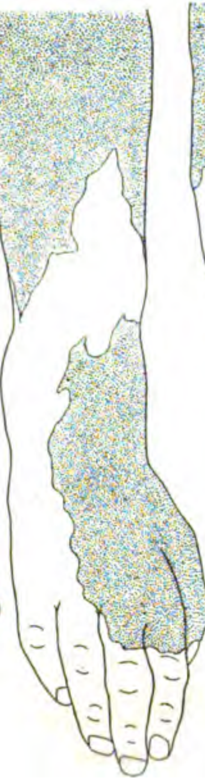
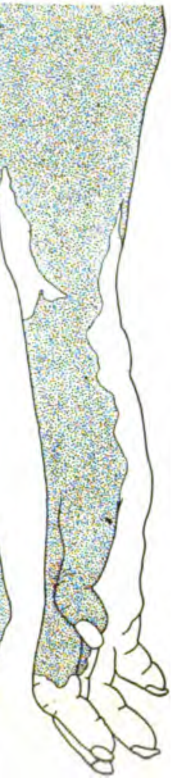
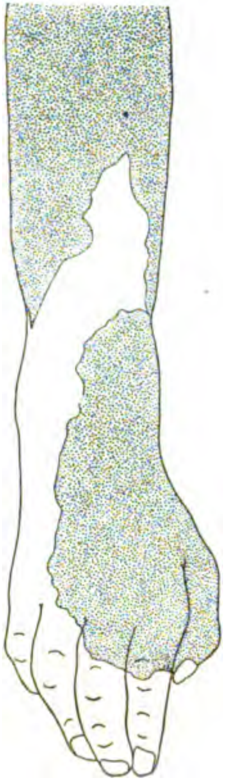


Fig. 3c.



March 30, '08.
Fig. 4a.



Oct. 6, '08.
Fig. 5a.

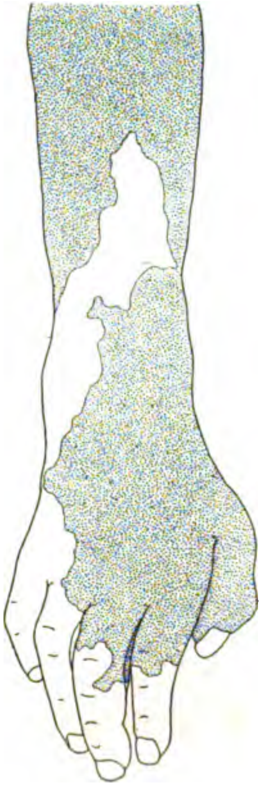


FIG. 1B.

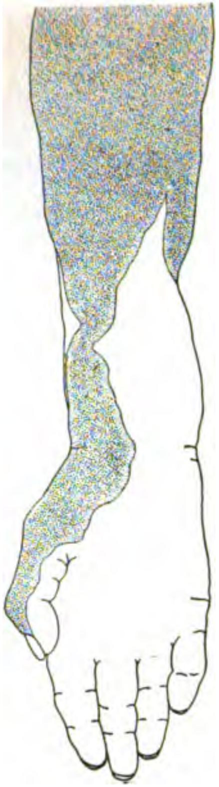


FIG. 2B.

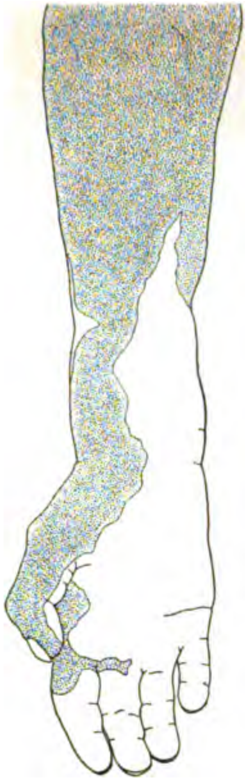


FIG. 3B.

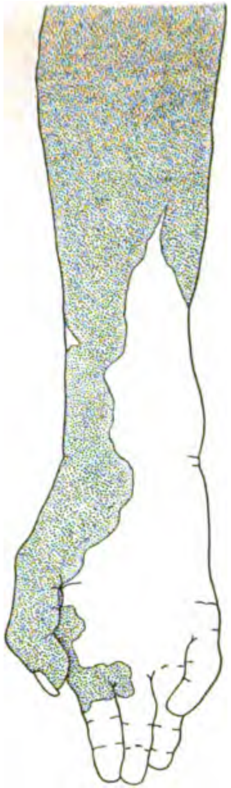


FIG. 4C.

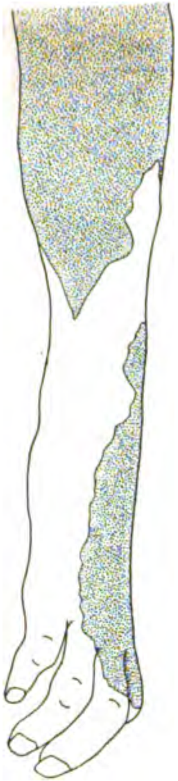


FIG. 4B.

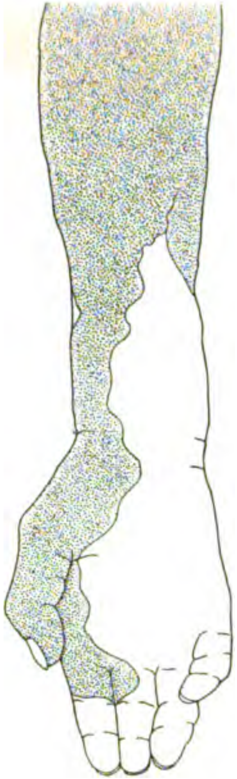
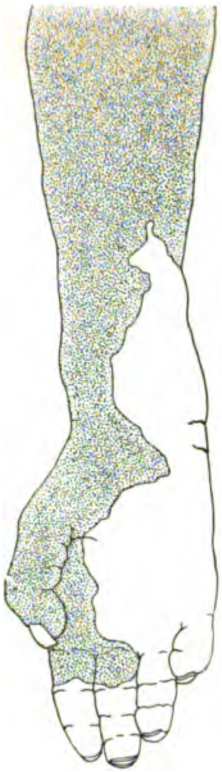


FIG. 5B.



[103] manifested on the hand, at least, could be interpreted as mediated through this nerve alone, and the boundary established on the hand could be considered the boundary of the area of this nerve. As indicated below, the nerves supplying the sensitive areas on the wrist and forearm, joining the area of the radial, could be quite approximately determined because their terminal twigs also had been practically isolated in the original destruction of tissue and by the grafting on of the flap of strange skin.

Considering the conditions always to be met in investigations of this kind, the boundary lines obtained in the frequent examinations were remarkably constant and the variations [105] manifestly indicating changes in innervation are considered quite trustworthy.

In the tracings of the photographs here given, the boundary lines with the variations due to changes in the innervated area do not appear throughout in their exactly true relative positions, due to the fact that the given positions of the hand, with reference to the camera, were not always exactly identical. The varying amounts of foreshortening, because of the slightly varying positions of the hand, have resulted to greater disadvantage in the tracings than showed in the photographs where the effects of shadow and perspective were present. Attempts were made to photograph in identical positions throughout, and the slight effects due to variations in the angles of exposure were not realized till the tracings were made and compared, which was after all the photographs had been taken. These effects, however, do not seriously obscure the few points of interest. The effect is most marked in comparing Fig. 2a with Fig. 3a. In Fig. 3a the ulnar side of the hand was turned outward, toward the camera, more than in Fig. 2a, in which the dorsum was squarely exposed.

The common or average areas of cutaneous distribution upon the hand and wrist of the ulnar, median and radial nerves are sufficiently familiar to all, so their description here is unnecessary. The usual territory supplied by each has been repeatedly determined by dissection, experimental stimulation after section, and by study after degeneration following accidental division or destruction of the nerves. The litera-

FIG. 6.

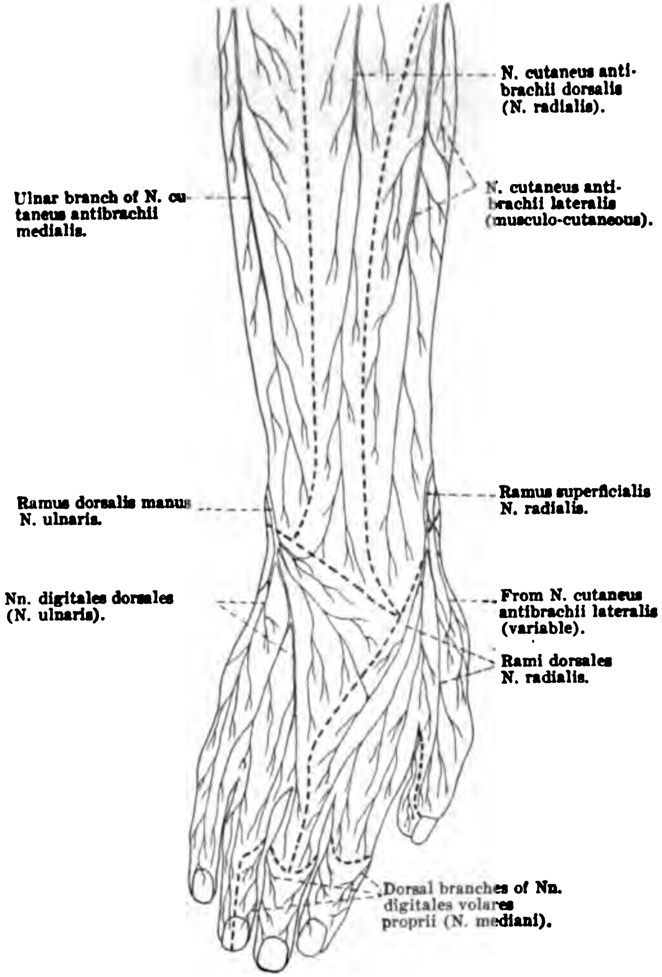
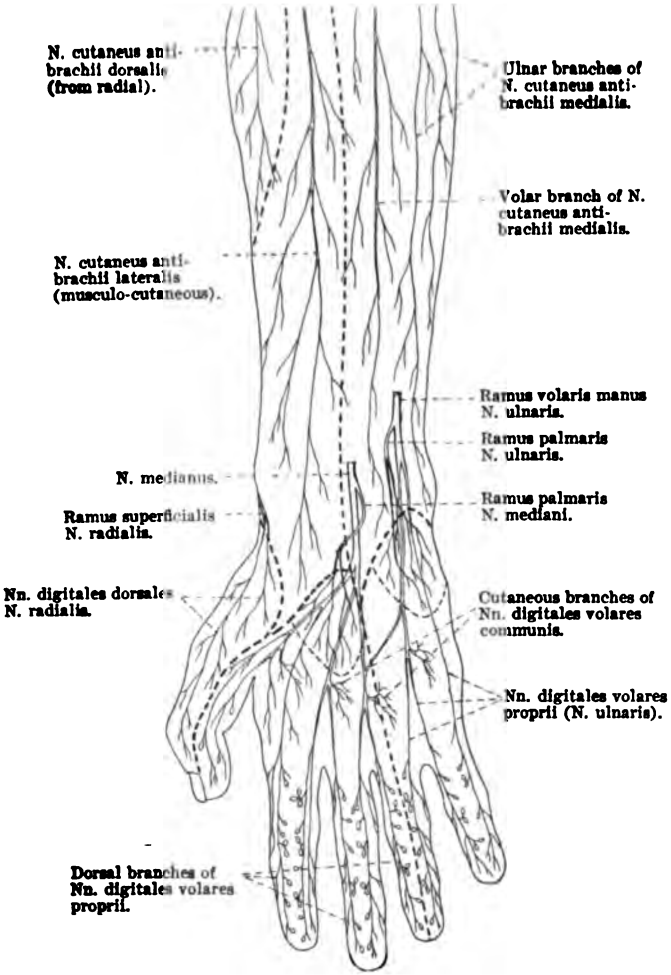

N. cutaneus antibrachii dorsalis (N. radialis).
Ulnar branch of N. cutaneus antibrachii medialis.
N. cutaneus antibrachii lateralis (musculo-cutaneous).
Ramus superficialis N. radialis.
Ramus dorsalis manus N. ulnaris.
From N. cutaneus antibrachii lateralis (variable).
Nn. digitales dorsales (N. ulnaris).
Rami dorsales N. radialis.
Dorsal branches of Nn. digitales volares proprii (N. mediani).

FIG. 7.


N. cutaneus antibrachii dorsalis (from radial).
Ulnar branches of N. cutaneus antibrachii medialis.
Volar branch of N. cutaneus antibrachii medialis.
N. cutaneus antibrachii lateralis (musculo-cutaneous).
Ramus volaris manus N. ulnaris.
Ramus palmaris N. ulnaris.
N. medianus.
Ramus palmaris N. mediani.
Ramus superficialis N. radialis.
Nn. digitales dorsales N. radialis.
Cutaneous branches of Nn. digitales volares communis.
Nn. digitales volares proprii (N. ulnaris).
Dorsal branches of Nn. digitales volares proprii.

[105] ture of the past 50 years abounds with descriptions of cases, most of them detached and more or less crude, but which, taken together, have rendered it possible to outline the normal or usual areas of distribution of each of the nerves. Likewise there are abundant papers and notes describing instances of abnormal distribution of these nerves. Kennedy[3] was the first to give a complete and systematic summary of the literature upon the regeneration of sectioned nerves, and to draw general conclusions as to areas of distribution upon the limbs based upon information assembled from numerous cases. Including that collected by Cruikshank, he gives a bibliography extending backward as far as 1537. Sherren,[4] in two lectures, sums up previous findings and opinions as to the areas supplied by the nerves to the limbs, combined with [106] results obtained by himself from personal study of 175 cases of nerve injury. Tonkoff[5] gives one of the collections of descriptions of abnormal arrangements of the cutaneous nerves to the back of the hand, comparing and explaining them on the basis of the normal arrangement of the same nerves in the apes.

For ready reference in connection with the case here in hand, Figs. 6 and 7 are given. These are compiled from various findings and similar diagrams in text-books of anatomy, and are considered as showing the average or usual cutaneous areas of the forearm and hand supplied by the respective nerves as indicated.

Several cases are recorded in which the ulnar and median nerves were severed. These may be divided into those in which the nerves were clean cut (glass cuts, knife wounds and all strictly localized injuries), and those in which the nerves were lacerated, accompanied by the destruction of considerable other tissue, as in the case here described. Sherren (loc. cit.) makes a distinction between subcutaneous sensations, "deep sensibility" or "deep touch," and direct cutaneous sensibility, "light touch," and states that "deep sensibility" is not present when the tendons of the extremity are destroyed or even [106] severed. He bases this conclusion upon the study of cases in which the cutaneous nerve branches are destroyed both with and without accompanying destruction of the tendons beneath. This probably means only a serious impairment of the subcutaneous sensations due to the severing of the nerves and the degeneration of the plexuses which accompany the tendons, many of whose fibers terminate upon the tendon sheaths and bones and in the muscles. In addition, a few of the sensory fibers ending in the subcutaneous connective tissue may not be severed with the division of the tendons, and there should remain, with severed tendons, a certain amount of deep sensibility dependent upon the cutaneous nerves proper.

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[3] Kennedy, R.: Phil. Trans. Royal Soc., Vol. 188, 1897, p. 257.

[4] Sherren, J.: Lancet, 1906, Vol. I, p. 727.

[5] Tonkoff, W.: Internat. Monatschrift für Physiol., Bd. 15, 1898, p. 156.

In the case here in hand, a considerable extent of the flexor tendons had been totally destroyed, but there was occasionally noted along the inner margins of the anesthetic area indications of deep sensibility under skin having no direct cutaneous sensibility. These were more frequently remarked during the latter part of the study, when regeneration of the cutaneous nerves had become a little more rapid. They are mentioned as indicating that the growing nerve twigs extend in the loose subcutaneous tissue in advance of the region in which they are actually terminating in the skin proper.

In the absence of the cutaneous supply to the hand from the ulnar and median nerves, the distribution of the radial (the only sensitive area remaining upon the hand) appeared to conform quite closely to the average or normal distribution of this nerve. On the dorsum of the hand, the area extended slightly upon the ulnar side of the first phalanx of the middle finger (Fig. 1a) instead of to the mid-line of this phalanx, and thence curved toward the ulnar side of the dorsum rather than toward the radial side, as does the average or normal area (Fig. 6). However, judging from the subsequent studies, this apparent abnormality of the area is considered as probably due in part to the compensatory extension of twigs from the radial already begun during the time between the injury and the time the first study (Fig. 1) was made, and partly, from above, to the terminal twigs of the lateral cutaneous antibrachial nerve.

[106] On the palmar aspect, the boundary line of the sensitive area was normal for the radial supply to the thumb, extending toward the volar surface to a line beginning at the lateral margins of the nail and passing thence parallel to its first and second phalanges (Fig. 1b). Thence, instead of curving radialward to terminate the area just above the radial edge of the wrist joint (Fig. 7), the boundary line turned medianward to include the greater part of the thenar eminence, and then upward upon the forearm to the line of suture of the skin flap grafted upon the forearm. This course is due to the fact that the cutaneous area of the radial nerve is joined on the thenar eminence by the area supplied by the lower end of the volar branch of the lateral cutaneous antibrachial (musculo-cutaneous) nerve, a part of which area here comprised the only isthmus of sensitive skin connecting the unaltered skin of the forearm, above the grafted area, with the hand (Fig. 3c).

The flap of the skin from the chest, grafted onto the forearm after removing the large amount of cicatricial tissue resulting from the original wound, was finally detached from the chest wall on January 28, 1907, and the final stitching into the forearm made. Thus it was during the month of February, 1907, that the usual sloughing and healing processes were completed, and it was not until the latter part of the October following that the patient was first subjected to the study described here.

Notwithstanding this length of intervening period, the first study with the esthesiometer revealed practically no invasion of cutaneous nerve fibers into the grafted area. Almost throughout its entire boundary the line of suture of the graft, which could be distinguished as a line of scar in the skin, was likewise the line of demarkation here between the sensitive and anesthetic surfaces. Much of the grafted area itself still had the characteristic smooth, glistening appearance, but with a color showing a better vascular supply than had the suture line.

Beginning with the bristle within the grafted area and working toward the suture line, no sensation was manifest during the first study till the suture line was crossed. Then, suddenly, on the immediate sensitive side of the suture line, [106] not only sensation was manifest but hyperesthesia and often of considerable amount. The patient would suddenly cringe, uttering a loud "yes." This is considered as indicating that the cutaneous nerve twigs, severed by the injury and operation, spreading in the corium toward the grafted area, and terminating in the stratum papillare and epidermis, had been resisted by the density of the scar tissue along the suture line. The obstruction had caused the growing ends to be reflected and become coiled up along the sensitive side of the scar line, [107] giving the skin immediate to the line an especially abundant innervation. In Figs. 1a and 1b the boundary shown of the anesthetic area of the forearm is coincident practically throughout with the line of suture of the grafted area.

In subsequent studies, when the tests showed that in places the growing nerve fibers were succeeding in breaking through the line of sutural scar tissue (Figs. 2a and 2b), the boundary of the anesthetic area became more and more irregular. And it is interesting to note that wherever along the line sensation invaded the anesthetic area by passing through the scar line, the line of hyperesthesia disappeared. Painfully sensitive before breaking through the scar, the line became normally sensitive afterward.

The obstructive effect of scar tissue against the extension of regenerating and growing nerve fibers is of common experience, especially as formed in the region of division of nerve trunks. Among others noting the effect, Holmes[6] reports a case of operation six months after the radial nerve had been severed, in which the end of the central stump was found involved in a dense knob of connective tissue. This knob had totally obstructed growth extension, and in it the regenerating fibers were coiled and gnarled, increasing its density.

One might expect that the anesthetic area of the forearm, represented by the area of the grafted skin-flap, would acquire its innervation, beginning along its upper border and gradually spreading from this border downward toward the hand. This would seem the natural direction of procedure from the fact the severed nerves which normally supply the

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[6] Holmes, T.: Lancet, 1883, Vol. I, p. 1034.

[107] lower part of the forearm are the terminal and downward-extending ends of the ulnar and volar branches of the medial cutaneous antibrachial nerve (internal cutaneous nerve), the lower cutaneous arm branch of the radial or musculospiral (N. cutaneus antibrachii dorsalis), and the terminal portions of the volar and posterior branches of the lateral cutaneous antibrachial nerve (cutaneous portion of the musculo-cutaneous nerve). The arrangement of these is indicated in Figs. 6 and 7. A wholly downward spread of the regaining innervation, however, was by no means the case. The spread of cutaneous sensibility from the original boundary into the anesthetic area was about as rapid from the sides and even from below as it was from above. The spread from below, because of the locality of the injury and the position of the grafted flap, was of necessity from the radial side, and is explained as due to the growth of lateral twigs from a probably uninjured terminal cutaneous branch of the musculocutaneous nerve and, further, to the growth of lateral twigs from the superficial branch of the radial (radial nerve of the older nomenclature). From the general downward normal direction of the twigs of the superficial branch of the radial, such lateral twigs from it into an area not previously supplied by it would indicate a tendency toward compensatory innervation on the part of the radial.

Compensatory extension of the area of the hand normally, and here originally, supplied by the radial was quite positively indicated. The first examination of the patient showed that the area of the hand supplied by the superficial branch of the radial corresponded quite closely to that usually given as the normal area of the radial (Figs. 1a and 1b). Though nine months had elapsed since the grafting of the skin and about two years since the original injury, so great had been the impairment of nutritive functions by the laceration and growth of scar tissue that at the first examination but little evidence was manifest of innervation advancing into the area rendered anesthetic. On the dorsum of the hand and wrist (Fig. 1a), the sensitive area extended further toward the ulnar side than does the usual area supplied by the dorsal branches of the radial (Fig. 6). This is explained above as due in part to the downward extension of the terminal twigs [107] of the lateral antibrachial cutaneous (musculo-cutaneous) nerve, which was probably uninjured by the accident and operation, and in part either to a larger dorsal area than usual supplied by the radial, or to an already begun compensatory extension of twigs from the dorsal branches of the superficial branch of the radial to the skin of the wrist and dorsum of the hand. It has been noted that the skin of the dorsum of the hand is not always supplied by the ulnar and superficial branch of the radial alone. Zander[7] called attention to the fact that twigs from the lateral cutaneous antibrachial (musculo-cutaneous) and the dorsal cutaneous antibrachial nerve (external cutaneous branch of the radial) may take part. The latter branch was involved in the injury and its area involved in the skin graft, so that it was not represented at all in the dorsum of the hand. The former nerve, however, was no doubt represented, and very probably took part in the upper part of the extension of the sensitive area.

The cutaneous supply over the dorsal surface of the first phalanx of the third or middle finger and the adjoining end of the third metacarpal was practically that usually given for the radial nerve, i. e., sensation was present over only the radial half of the first phalanx and the line curved slightly ulnarwards over the third metacarpal.

The radial supply to the skin of the thumb, at the time of this first examination, was likewise that usually described. Normal sensation was present over the dorsal or outer surface of the thumb, but only over the root of the nail (the skin forming the vallum unguis). Along the lateral aspects of the thumb the sensitive area was sharply bounded by lines continuous with the lateral margins of the nail. On the mesial side this line curved slightly from the margin of the nail toward the volar surface and then became straight along the side of the thumb. The line on the lateral side was quite straight on the extended thumb, parallel to and continuous with the lateral margin of the nail, till, reaching the palmar surface covering the first metacarpal, it curved mesially to in-

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[7] Zander: Berliner klinische Wochenschrift, 1890, No. 8.

[107] clude the greater part of the thenar eminence. Thence it did not follow the margin of the usual radial area by curving lat-
[108] erally to the radial margin of the wrist. This was obviously because of the fact that the sensitive area of the radial was joined on the thenar eminence with the area supplied by the terminal of the volar branch of the lateral cutaneous antibrachial nerve (Fig. 7).

From Fig. 1 to Fig. 5, a and b, the tendency toward compensatory extension manifested by the radial nerve during the months under observation may be seen. A study made between those represented by Figs. 1 and 2 showed a beginning extension of the area of the radial on both the mesial and lateral sides of the thumb and toward the volar surface of the index finger. However, the portion of the sensitive area first to reach the actual palmar surface extended from the dorsal aspect in between the index and middle fingers instead of passing around the lateral aspect of the first phalanx of the index finger. In Fig. 2b this had fused with the extension around the index finger and second metacarpal. Two months later (Fig. 3b) the entire thumb was normally sensitive, and the new palmar area had extended slightly. Thence the compensatory extension continued, though remarkably slowly, both on the palmar surface of the hand and outward on the dorsal aspect of the three fingers and hand, as shown in the figures. The remarkably slow extension was probably due to two causes: (1) the impaired vascular supply to the hand and, therefore, the impaired nutrition, and (2) to the fact that the extending nerve fibers had to penetrate absolutely new and, to them, strange territory, being neither nourished nor guided along paths of least resistance by the terminal stumps of degenerating fibers. Further, it is probable that the fibers so extending were not only slow but were few at the time. Ingbert[3] has computed that in the cutaneous innervation of man, one fiber in an arm nerve supplies an average of 1.3 sq. mm. of skin. Thus comparatively few fibers may have been taking part in the compensatory extension.

As mentioned in the history of the case, Dr. Sherman made an attempt to unite the stump of the median nerve to the trunk of the radial, but taking especial care not to injure the radial. There is a remote possibility that the extension of the hand area of the radial may have been accomplished by fibers grown onto the radial from the median nerve. This is very improbable, however, for the median nerve could have been, with safety, scarcely more than inserted into the sheath or epineurium of the radial, and the density of this sheath would offer greater obstruction to the fragile regenerating ends of the median nerve fibers than would the much looser areolar fascia about it. Further, the distance these fibers would have to extend, compared with the rate at which regeneration was taking place in the other localities of the forearm, and the probable total absence of the guiding influence of degeneration in the radial render very doubtful the presence of median nerve fibers in the terminal twigs of the superficial branch of the radial. [108]

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[3] Ingbert, Charles: Jour. Comp. Neurology and Psychology, Vol. 13, 1903, p. 209.

After having the patient under observation for about a year, he was allowed to go unmolested further and, expressing an intention to return to the mining region whence he came, he was lost sight of.

DESCRIPTION OF FIGURES.

FIGS. 1a to 5b.—Tracings made from a series of photographs taken of the injured forearm and hand at the intervals indicated during one year. The boundary between sensitive and non-sensitive areas was in each case indicated on the hand, and in the photographs, by a line of ink, not shown in the tracings. Instead, the sensitive areas are stippled to the position of the line, leaving the non-sensitive areas blank. In each figure, a and b are respectively the dorsal and volar surfaces as photographed after the same study. Fig. 3c shows the radial aspect at the same period as Figs. 3a and 3b, and Fig. 4c shows the ulnar aspect at the same period as Figs. 4a and 4b.

FIGS. 6 and 7.—Diagrams considered as showing the more common cutaneous areas of the dorsal and volar surfaces of the forearm and hand supplied by the nerves indicated. The overlapping of the areas is intentionally omitted.

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ADULT HUMAN OVARIES WITH FOLLICLES CONTAINING SEVERAL OÖCYTES

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FOUR FIGURES

The two ovaries dealt with below were obtained at autopsy for histological purposes in this laboratory in the fall of 1909 from a negress eighteen years old. Macroscopically they appeared perfectly normal. There was no history taken of the case. When the sections were given out to the class it was found that many follicles contained more than one oöcyte. It was suggested by Professor Hardesty that it might be of interest to describe the conditions found and he kindly assigned the material and the problem to me.

The ovaries were fixed in Zenker's fluid, cut transversely in celloidin at 20 micra thick, mounted serially and stained with haematoxylin and congo red. The accompanying figures were made with the aid of the camera lucida. The epithelial lining of the Fallopian tubes showed satisfactory fixation, the cell boundaries and cilia being very well defined in the sections. The connective tissue in the ovaries appeared in normal proportion, the distribution of the follicles appeared normal, and the follicular epithelium was well fixed.

Follicles containing more than one oöcyte were found to be remarkably abundant. The greater number of these were in the earlier or smaller stages, varying from a follicular epithelium of one layer of cells to stages showing the beginning of the corona radiata. Of the larger follicles only, beginning with those far enough advanced to show the first appearance of liquor folliculi, one of the ovaries showed forty-five such follicles containing more than one oöcyte. The figures below represent an accurate counting of the oöcytes in each of all the follicles that were large enough to show a liquor folliculi developed:

The first ovary studied gave:

17 follicles containing 2 oöcytes
6 follicles containing 3 oöcytes
12 follicles containing 4 oöcytes
7 follicles containing 5 oöcytes
2 follicles containing 7 oöcytes
1 follicle containing 11 oöcytes

In the second ovary of the pair there were counted:

18 follicles containing 2 oöcytes
4 follicles containing 3 oöcytes
8 follicles containing 4 oöcytes
5 follicles containing 5 oöcytes
2 follicles containing 6 oöcytes
2 follicles containing 8 oöcytes
1 follicle containing 9 oöcytes
2 follicles containing 10 oöcytes
1 follicle containing 13 oöcytes

Thus, in the two ovaries of the individual there was found a total of eighty-eight of the larger follicles containing more than one oöcyte. The counting of the oöcytes was confined to those sections of them in the series which contained the 'germinal spot' or nucleolus.

All of the sections of the first ovary studied were not available in series, a batch having been issued by the technician to the students for class work in organology before the peculiarity was observed. The section of the follicle represented in figure 1 may be taken as an example of the appearance of the polyovulation found.

The particular follicle represented in figure 1 contained eleven oöcytes measuring from 110 to 180 micra in diameter, with a total average diameter of 151 micra. This follicle was not spherical in the preparations. Measured transversely in three planes from the membrana propria of the stratum granulosum on the two sides, a mean diameter of 437 micra was found for it. Its longest diameter was found to be parallel with the long axis of the ovary and therefore had to be obtained by counting the sections in the series through which it appeared cut and multiplying by the known thickness of the sections. All of the oöcytes were attached to the stratum granulosum by means of cumuli oöphori. However, five of them in this case were attached at the same point by means of a common pedicle, appearing through the sections collected in a grape-cluster with a common cumulus, four being attached to the fifth and this attached in the usual manner. All of the eleven oöcytes in this follicle were normal in structure and were approximate in size to the diameters considered normal for this stage of the follicle.

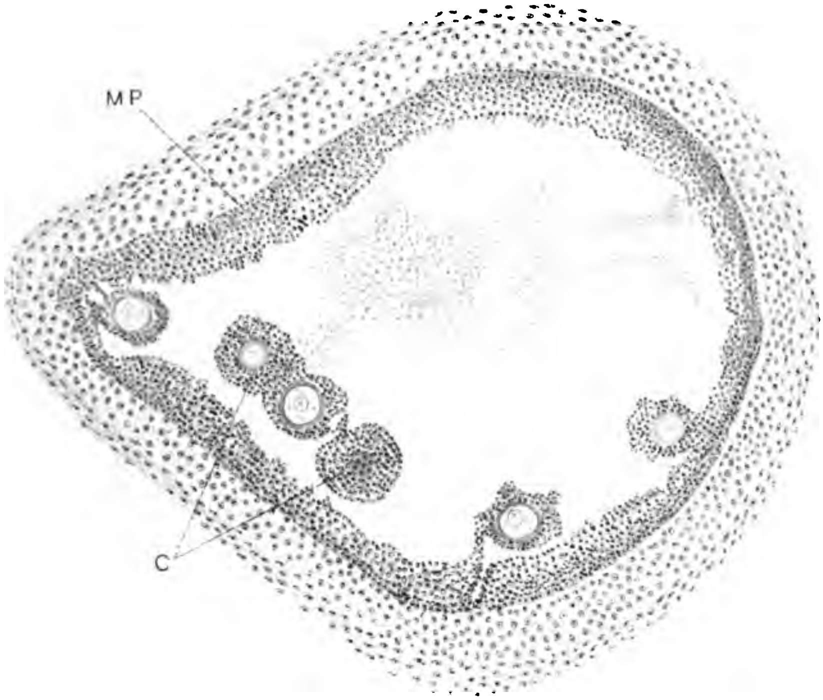

Fig. 1 showing a polyovulated Graafian follicle which contained eleven oöcytes. The drawing is reconstructed as far as the oöcytes are concerned from a series of 12 sections each 20 micra in thickness. From the ovary of a negress of eighteen years. *C*, portion of a cluster of oöcytes; *MP*, membrana propria of stratum granulosum. × 57.

The follicle represented in figure 2 is of another type of polyovulation found to be about equally common as that of figure 1. In this the oöcytes vary markedly in size, some being three times the diameter of others. This follicle was but approximately half the size of that shown in figure 1. It contained, through the series of sections, thirteen oöcytes of which five were large, averaging 150 micra in diameter, the remaining eight being smaller. Three of them were especially small, not measuring above 50 micra in diameter. All the thirteen oöcytes here were attached separately to the stratum granulosum by pedicles varying but slightly in width and with cumuli oöphori in about equal amount.

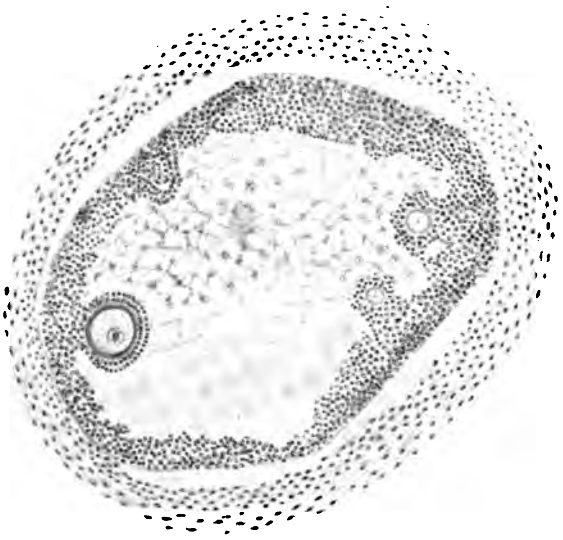

Fig. 2 A section of a polyovulated Graafian follicle from the same individual as figure 1. Shows a type in which the oöcytes vary in size. × 57.

In studying the smaller follicles, most of which were situated nearer the periphery of the ovary, it was observed that a large number of those containing more than one oöcyte presented the gradation shown in figure 3. This figure was drawn to represent a smaller follicle, *A*, not yet developing a liquor folliculi and in which the oöcytes were of the same size, and to represent, *B*, a smaller follicle with liquor folliculi beginning to form and with one oöcyte larger than the others. These conditions were observed in a large number of such follicles and polyovulated follicles of similar sizes were much more numerous than the larger sizes represented in the previous figures.

The staining reaction appeared the same in all respects in both the large and the small oöcytes, the histological picture showing no indication of degeneration in any case observed beyond the variations in size.

There were quite a number of polyovulated follicles about as large as the one shown in figure 1 which were found to contain from two to six oöcytes of large size and of perfectly normal appearance. The largest follicle observed in either of the ovaries gave an average diameter of 633 micra. This contained only one oöcyte whose measurements gave a diameter of 201 micra. There were two other follicles both larger than the one shown in figure 1, each of which contained but one oöcyte. Thus it may be seen that the polyovulated follicles did not comprise the largest follicles.

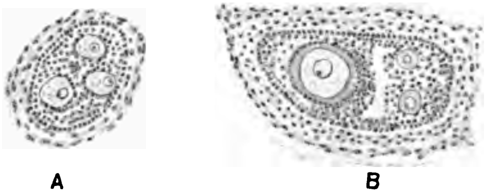

Fig. 3 Drawing, showing sections of two smaller polyovulated Graafian follicles from same source as figures 1 and 2. *A*, a smaller follicle with oöcytes of equal size; *B*, a smaller follicle with oöcytes of varying size. × 57.

Lying in the peripheral stroma of both the ovaries, mostly subjacent to the tunica albuginea, were the numerous primitive follicles found in all individuals. These follicles for the most part showed the usual one layer of low epithelial cells enclosing an oöcyte of the smallest size (*A* and *PF*, fig. 4). Occasionally, near the periphery, several of these small oöcytes appeared closely associated with each other, unevenly surrounded by an irregular line of dispersed nuclei which no doubt represented follicular epithelium in single layer.

Another interesting and seemingly unusual observation could be made in the sections of these adult human ovaries. The germinal epithelium (*GE*, fig. 4) appeared to be still proliferating and showed quite a number downfoldings or invaginations into the stroma below. One stage of such invagination is indicated in figure 4, *I*. Many stages of this could be found, including stages in which the downcroppings of the epithelium was partially and also wholly constricted from its continuation with the superficial epithelial covering, giving the appearance of short, wide tubules in the immediately underlying stroma. In no case, however,

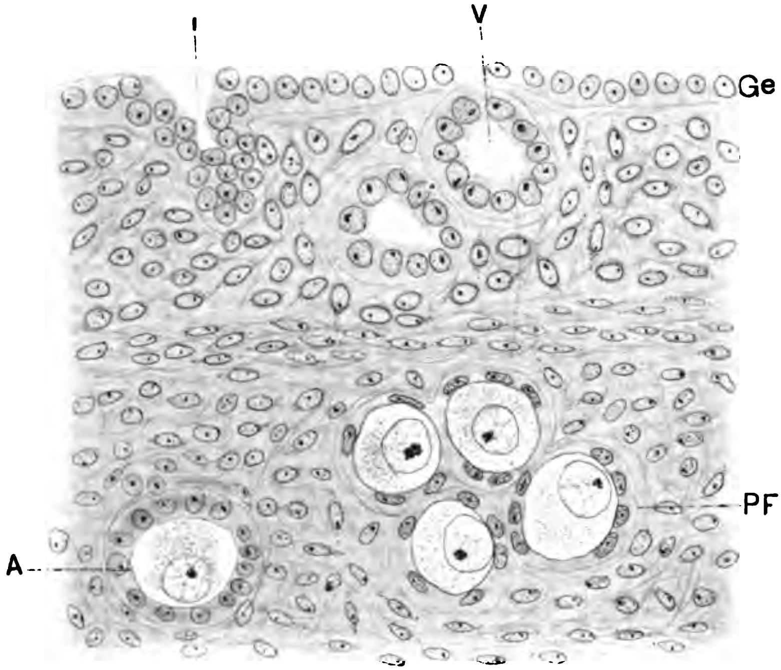

Fig. 4 Drawing, showing vertical section of superficial area of ovary used for previous figure. *Ge*, Germinal epithelim; *I*, invagination or down cropping of germinal epithelium; *V*, vesicle or follicle without oöcyte; *PF*, primary or resting follicles; *A*, primary follicle beginning further development. × 280.

did any of the cells of these downcroppings, or tubules, show any sign of differentiation into primitive oöcytes. Further, follicles, or rather vesicles, could be often observed consisting of a wall of a simple layer of cells of the size of those comprising the germinal or superficial epithelium, and in every way suggesting recent formation, but, in no case did any of these follicles contain a vestige of an oöcyte. They merely enclosed a cell-free space as shown in figure 4, *V*. A theca folliculi about these vesicles was no more definitely formed than about the ordinary primitive follicles.

If, as is generally believed, the invagination of the germinal epithelium with the differentiation of certain cells into oöcytes and the formation of 'egg tubes,' 'egg nests,' and primitive follicles, terminates before or shortly after birth, or certainly before the eighteenth year, then such a downcropping and evidently resultant vesicles as seen here must represent a period in which follicles are formed but not oöcytes. None of these empty vesicles were found of larger size nor were any observed indicating increase in size by further growth.

It is not the intent of this paper to try to explain the occurrence of the several oöcytes in a single follicle. The phenomenon seems to be considered one of very rare occurrence. The first notice I have found of such in the literature is that of Waldeyer in 1870. His illustration, from the ovary of the dog, is given in Huber's revision of Böhm and Von Davidoff's Histology ('00) and is also copied by Schafer in the latest edition of Quain's Anatomy, volume 2, part 1, 1912.

Van Beneden ('80) observed in the ovary of the 'horse-shoe bat' follicles containing two or three, and in one case a follicle with four oöcytes. These oöcytes were of varying size and none of the follicles containing them were advanced to the stage showing liquor folliculi or follicular cavities. Schöttlander ('93), working with human material, all of which was admittedly pathological, describes numerous small follicles containing two or three oöcytes. Practically all in this condition possessed a follicular epithelium of but one layer of cells and these were of the primitive type. All were in ovaries of foetuses of varying ages and at term. He described some follicles, somewhat more advanced, in which there appeared a large but abnormal oöcyte in the center of the follicle while certain cells of the follicular epithelium appeared enlarged as though differentiating into öocytes. These latter he called 'accessory ova.' He considered all the cases of polyovulation observed by him as degenerative conditions.

Stoeckel ('98), also working with human material, found in the ovary of a woman of twenty-nine years, several follicles containing two or more oöcytes. This is the only reference I have found in the literature in which polyovulation has been observed in adult human material. Bouin ('00), reports finding in the ovary of the dog follicles containing two, and some, three, oöcytes. He describes one follicle in which he estimates the presence of ten oöcytes. All these, he describes as perfectly normal in appearance, the latter case being a larger follicle with perfectly normal stratum granulosum, and none of them showed any sign of pyknosis or other degenerative changes.

Honoré ('00), working with ovaries of the rabbit, describes a few follicles containing more than one oöcyte and one containing as many as four. These oöcytes were of varying size in the follicle, and the follicles were of the smaller stages. The follicle containing four oöcytes showed one in its center while the other three were much smaller and were buried among the cells of the follicular epithelium, similar to those described by Shöttlander.

He describes these smaller buried oöcytes as undergoing atrophy. He cites Nagel and Rabl as having observed polyovulation but does not state the animals in which they found it and I have not been able to consult their papers.

The Bouins ('00) described a follicle in the ovary of the adult bitch which contained eleven oöcytes. These were very varied in size and position, the smaller being buried among the cells of the follicular epithelium as was observed by Honoré.

As to the origin or cause of such polyovulation, Bouin and Honoré considered these several oöcytes as having been imprisoned in the same connective tissue theca at the time of the closing off or constriction of the egg tubes or egg nests into separate follicles.

Waldeyer thought that, in the polyovulation observed by him, the additional oöcytes arose by mitotic division of the oöcyte previously existing in the follicle, and Nagel, quoted by Honoré, seems to have supported Waldeyer in this view.

Stoeckel held that polyovulation results from the cytoplasmic division in a follicle of oöcytes originally containing two or three nuclei, and that the separate oöcytes thus arising become dispersed in the follicle by the subsequent proliferation of the cells of the follicular epithelium.

Rabl, quoted by Honoré, held that the follicular epithelium encloses more than one oöcyte from the beginning of its formation. This may mean that from the stage commonly known as that of the 'egg nests of Pflüger,' two or more closely associated oöcytes may become surrounded by a common follicular epithelium and thus remain. He believed that polyovulated follicles are subsequently separated into monovulated follicles by the proliferation and ingrowth of the follicular epithelium, followed by the ingrowth and development of the theca folliculi. This view, however, can apply only to the younger stages of follicular development and not to the conditions found in larger follicles as observed in this paper. Honoré himself seems unable to arrive at a definite explanation of polyovulation, but is inclined to support the views of Rabl.

In the adult human ovary here mentioned, the tissues in all respects seemed normal. No evidences of degeneration were observed and the material was well fixed. The only peculiarities noticeable were the abundant instances of polyovulation and the evident downcropping at this age of the germinal epithelium and the formation of vesicles or follicles not containing oöcytes. No evidence of cell division, nuclear or cytoplasmic, were noticed in any of the oöcytes. Therefore it is improbable that the views advanced by Waldeyer, supported by Nagel, and that advanced by Stoeckel are applicable in this case. The fact that in about one-half of the polyovulated follicles studied here certain of the oöcytes were much smaller than others may indicate that these smaller oöcytes have been arrested in their development. Very probably such would degenerate during the further advancement of the process of ovogenesis. Possibly all would disappear except one. Or, possibly all such follicles would undergo *atresia* and thus never reach the stage of extrusion of the ovum.

In the series of sections of these ovaries, there may be seen in the stroma immediately underlying the tunica albuginea and among the primitive or resting follicles, series of smaller oöcytes closely associated in lines of three or four, an entire line being bounded about by a single line of nuclei of follicular cells but with no follicular cells between the oöcytes. Again, small clusters of oöcytes appear in which certain of the oöcytes seem to lack a separately distinct follicle. This condition is partially indicated with two of the oöcytes shown in figure 4, *PF*. It is therefore, possible that some of the polyovulated follicles of the advanced stages may result from the development of a common follicular epithelium about two or more oöcytes.

Of course, nothing definite may be advanced as to whether two or more oöcytes in a follicle ever proceed in their development though the stages of maturation and thence result in an expulsion of two or more ripe ova from a single follicle.

I wish to acknowledge my indebtedness to Professor Hardesty for his suggestions and guidance in the preparation of this paper.

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A MODEL DEMONSTRATING THE CHANGES IN POSITION AND PERITONEAL RELATIONS OF ABDOMINAL VISCERA DURING DEVELOPMENT

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THREE FIGURES

Differences in position of the abdominal viscera and in their peritoneal relations at various stages of development occupy the front rank of difficulties which confront the teacher of anatomy. Text-books are lavish in detail, and clearness of description is not lacking in either text or atlas. The fact remains, nevertheless, that but few students obtain a clear idea of the successive changes which occur in the abdominal cavity during growth from the simple arrangement of the gastro-intestinal canal and its common mesentery in the early foetus to the complicated conditions acquired at term.

Huntington meets the difficulty by comparing the dissection of the human abdomen with that of the cat, and a better illustration cannot be found to substantiate the value of comparative anatomy in the study of the development of human organs. Huntington's method consists in directing the student to make comparisons between the abdominal viscera of the cat and those of the human subject. Advantage is taken of the fact that the peritoneal arrangement of the adult cat is much like that of the human foetus in early development. By a series of manipulations of the viscera of the cat, those movements and displacements of the organs, which occur later in the foetus and which result in the permanent fixation of peritoneal relations, may be imitated.

Suggested by Huntington's method, a model is herewith presented which has been found to simplify to our students, the explanation of processes by which the adult conditions in the human are attained. An apology for crudeness of the model should be offered. In its favor is the simplicity of its construction which is suggestive of simplicity rather than complexity in developmental processes. By manipulations of the organs represented, one may easily demonstrate the movements in rotation of the stomach and in torsion of the mesentery upon which the various changes in subsequent peritoneal relations essentially depend.

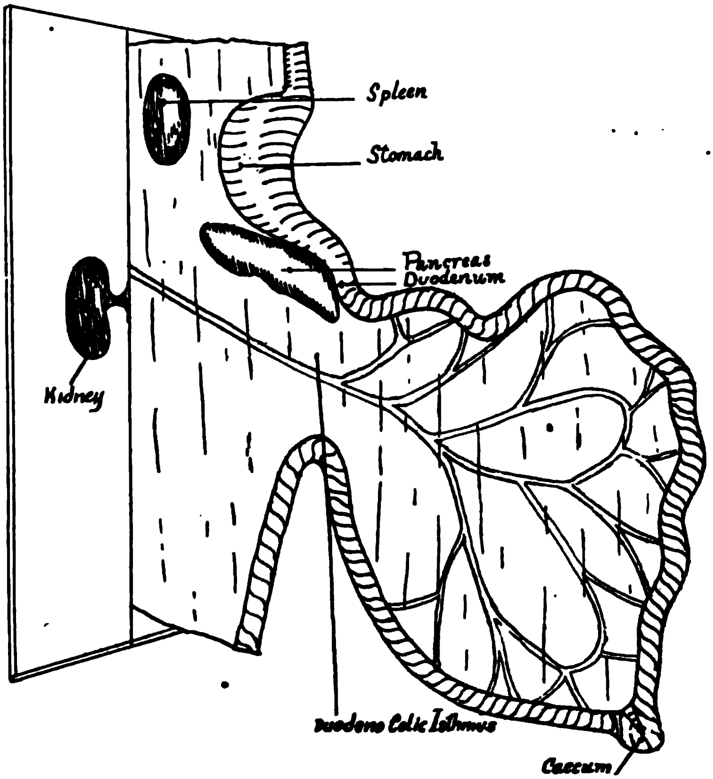

Fig. 1. Model representing gastro-intestinal canal before rotation of stomach and intestine.

A board about 2 feet long and 7 inches wide (fig. 1) represents the posterior abdominal wall and a piece of muslin covering it represents the foetal parietal peritoneum. To the mid-line of the board is attached a double layer of muslin, the common mesentery. In the upper part of this, the mesogastrium, are enclosed the stomach, pancreas and spleen, and its lower part is made up to represent the mesentry proper, which encloses the primitive intestinal loop with some development of intestinal coils in the upper limb of the loop and the caecum and the colon in the lower limb. The stomach, pancreas, spleen and kidneys are represented by cotton cushions and the intestinal canal by a soft cotton rope. The duodeno-colic isthmus is shown with the superior mesenteric vessels passing to the intestine.

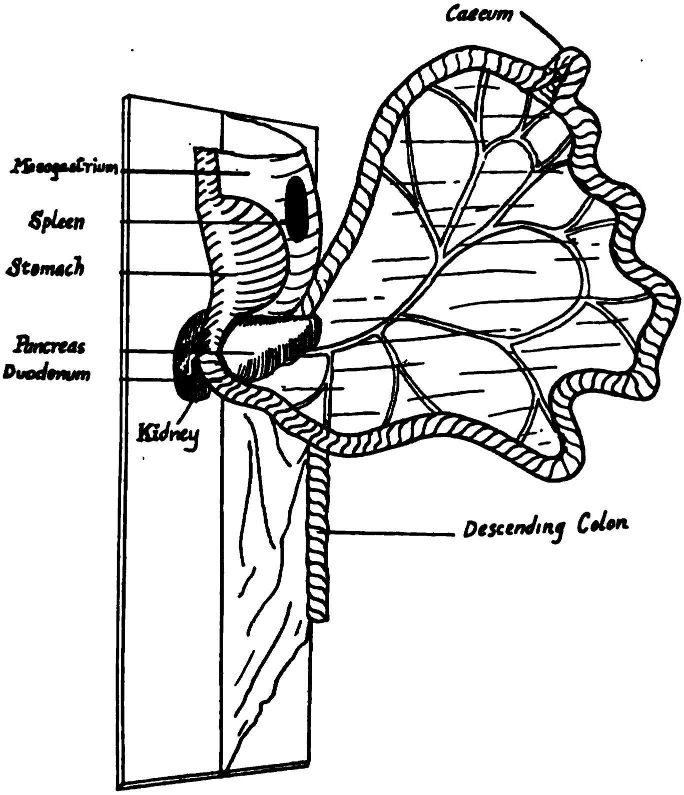

Fig. 2. Model showing change in relations of viscera attending rotation of stomach; figure shows also first step in twisting of the mesentery at the duodeno-colic isthmus.

The formation of the bursa omentalis and foramen of Winslow is illustrated by rotating the stomach from the sagittal to the transverse plane and by folding the mesogastrium (fig. 2). The ventral part of the fold then corresponds to the gastro-splenic omentum, the dorsal part of it to the posterior ligament of the spleen, and incidentally the displacement of the vagi nerves from the sides of the oesophagus to its ventral and dorsal surfaces is demonstrated. Rotation of the stomach is accompanied by rotation of the pancreas and duodenum which latter are thus made to leave their sagittal position for the transverse. The movement of twisting of the mesentery is next performed: the small intestine is made to sweep from right to left below the large intestine, the caecum is carried up from left to right and above the small intes-

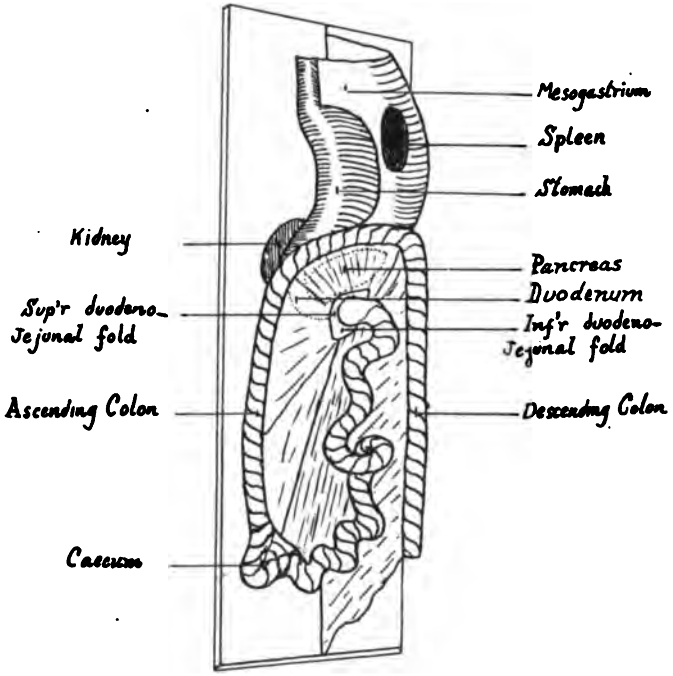

Fig. 3. Model shows position of abdominal viscera after rotation of stomach and complete twisting of mesentery.

tine as in figure 2, and in its travel, the ascending meso-colon is made to pass over the duodenum and pancreas which have rotated with the stomach and have been made to lie in the transverse plane. After this twisting of the mesentery on the duodeno-colic isthmus has been understood, it is quite easy to explain how the ascending meso-colon, pressed backwards by the developing convolutions of the small intestine, eventually becomes a parietal layer, and how the pancreas and duodenum, which have been caught behind the ascending meso-colon, lose their embryonic peritoneal covering and appear to have developed in a post-peritoneal position (fig. 3). The jejunum is now seen emerging from behind the newly acquired parietal peritoneum and at the duodeno-jejunal angle, the superior and inferior duodeno-jejunal folds and fossae (fig. 3) may be imitated by the twisting of the mesentery.

The peritoneal and non-peritoneal areas of the kidneys are made clear and the occasional persistence of the descending meso-colon, in contrast to the more constant disappearance of the ascending meso-colon, is explained by the more extensive travel of the caecum and ascending colon, in comparison with the relatively stationary position of the descending colon.

Finally after the disappearance of the ascending meso-colon has been demonstrated, the new line of attachment of the root of the mesentery proper explains itself.

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A COMPARATIVE STUDY OF THE THREE PRINCIPAL REGIONS OF THE SPINAL CORD IN A SERIES OF MAMMALS

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TWENTY-FIVE FIGURES

This paper presents some observations based on the study of transverse sections of the three principal regions (intumescentia cervicalis, intumescentia lumbalis, and middle of pars thoracalis) of the spinal cord in a series of twenty-four mammals. An outline drawing of a transverse section of the cords in each region is included together with tables of measurements showing variations in dimension and structure of the cords in the different mammals.

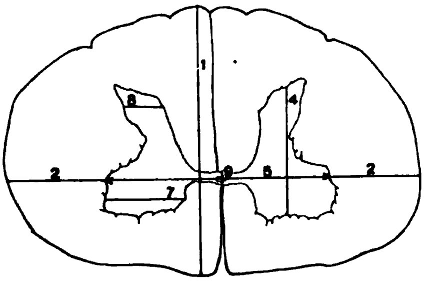
MATERIAL AND METHODS

In most cases one representative only of a species of mammal was studied. Hence all error due to individual variation is included in this work. An average taken from the study of a large number of individuals of each species would obviously be of greater value. In so far as was possible to ascertain, all animals used were normal. A few of the specimens were kindly furnished by Professor Hardesty with the sections ready for study. The method by which they had been prepared, and which was used for the remaining specimens of the list is, very briefly, as follows.

Most of the spinal cords were removed entire from the vertebral columns as soon after the death of the animal as possible and placed in a 10 per cent solution of formalin. After fixation a segment through each of the enlargements (cervical and lumbar) and the smallest portion of the thoracic region was cut from the cord. The blocks which were taken from the sixth cervical, the eighth thoracic, and the third lumbar segments were mordanted five to ten days in Muller's fluid, embedded in celloidin, and sections cut at 30 micra. The sections were stained by Pal's modification of the Weigert method for medullated nerve fibers.

Drawings. The figures were made in outline by means of the Edinger projection apparatus set for a magnification of eight diameters. They are not intended to present detail of structure but are of value in comparing the form of the several components of the different cords. What little detail is given, however, was obtained with the compound microscope (Leitz, Objective 2, Ocular 3). In the case of the lumbar regions of the ox and of the horse, one side of the largest segment of which was slightly injured in removing the cord, bilateral symmetry was assumed and the injured side was reconstructed from the intact half. With the exception of the lumbar region of the elephant which I was unable to obtain, the three drawings from the cord of each animal in the series is complete.

Tables. Data obtained for use in making the numerous general comparisons of the structures of the spinal cord is accumulated in the following tables with the animals arranged according to body weight. Table 1 gives a complete list of the animals with body weights. The underscored figures are true body weights of the animals, the others approximate. Tables 2, 3, and 4 record for each region certain measurements taken according to the scheme shown in text figure A the lines in which indicate the extent and direction of each measurement. The numbers of the lines in this figure correspond to like numbers in the tables. In all cases measurements of each half of the cord were taken and the average recorded after dividing by eight, the magnification represented by the drawings. Table 5 is constructed from the data in tables 2, 3, and 4 and is described in the discussion of it. Table 6 records the exact areas of the several components of the cord as obtained by tracings of the drawings with the Amsler planimeter. Separate readings were taken for the area of the grey figure, the area of the dorsal funiculus, and the total area. Other measurements were obtained by computing differences. Each tracing with the planimeter was taken three times and the average computed to minimize mechanical errors. The average of the three readings, which were in terms of square centimeters and fractions of square centimeters including vernier readings, were reduced by sixty-four, the square of the magnification. The actual areas of the specimens thus obtained are here recorded in terms of square millimeters. For the sake of convenience, I have selected certain data from table 6 and compiled the tables of ratios, 7, 8a, and 8b.



Text figure A. Outline of a section of the spinal cord with lines, numbered, indicating the extent and direction of each of the measurements taken of the different sections of the various spinal cords dealt with. These measurements are recorded in tables 2, 3, and 4. The numbers of the lines correspond to like numbers in the columns of the tables: *1*, dorso-ventral diameter; *2*, lateral diameter; *4*, thickness of grey figure; *5*, width of grey figure; *7*, width of ventral horn; *8*, width of dorsal horn; *9*, width of grey commissure.

TABLE 1

Table 1 gives the mammals used arranged in series in order of their absolute and approximate body weights. In case of certain of the specimens, obtained some years ago by Professor Hardesty and some obtained since, the body weight was not determined and here had to be estimated. The underscored weights are absolute weights, the others are approximate.

	KILOS	POUNDS
Elephant (Elephas indicus)	3,628.736	8000
Horse (Equus caballus)	566.990	1250
Ox (Bos taurus)	430.910	950
Brown bear (Ursus americanus)	136.077	300
Hog (Sus scrofa)	68.038	150
Man (Homo sapiens)	72.574	160
Sheep (Ovis aries)	34.019	75
Kangaroo (Macropus giganteus)		
Black crested ape (Macacus inuus)	5.216	
Dog (Canis familiaris)	5.000	
Gray fox (Urocyon cinero-argentatus)	3.940	
Lynx (Felis rufus)	3.050	
Raccoon (Procyon loctor)		
Rhesus monkey (Macacus rhesus)	2.720	
Opossum (Didelphys Virginiana)		
Cat (Felis domestica)	2.300	
Spider monkey (Ateles paniscus)	1.650	
Java monkey (Semnopitheous maurus)		
Rabbit (Lepus cuniculus)	1.560	
Agouti (Dascyprocta agouti)	1.350	
Guinea-pig (Cavia copaya)	.610	
Gray rat (Mus Norvegicus)	.500	
White mouse (Mus musculus, albus)	.027	
Bat (Nyctinomus brasiliensis nasutus)	.016	

TABLE 2

Measurements of cervical region in millimeters. Table 2 includes measurements of transverse sections from the cervical enlargement. The numbers in the heads of the columns correspond to the lines of measurement so numbered in text figure A, and the figures record actual size of the sections.

ANIMAL	1. DORSO-VENTRAL DIAMETER	2. LATERAL DIAMETER	3. MEAN DIAMETER	4. THICKNESS GREY FIGURE	5. WIDTH GREY FIGURE	6. MEAN GREY FIGURE	7. WIDTH VENTRAL HORN	8. WIDTH DORSAL HORN	9. WIDTH GREY COMMISSURE
Elephant	17.06	29.78	23.42	8.21	13.68	10.94	6.00	4.43	1.12
Horse	13.43	23.28	18.35	7.28	8.81	8.04	4.00	2.50	0.68
Ox	11.15	17.85	14.50	5.56	7.18	6.37	3.84	2.60	0.56
Bear	11.06	13.65	12.35	5.87	7.75	6.81	3.37	1.60	1.12
Hog	9.71	11.00	10.35	5.18	4.00	4.59	2.62	1.18	0.43
Man	8.93	13.81	11.37	4.25	7.12	5.68	2.75	1.37	0.62
Sheep	8.92	11.18	10.05	4.87	5.12	4.99	2.78	1.85	0.75
Kangaroo	7.50	8.84	8.17	3.58	3.12	3.35	1.43	1.75	0.87
Ape	6.60	7.71	7.15	3.62	3.62	3.62	1.82	1.12	0.62
Dog	5.21	7.81	6.51	3.06	4.87	3.96	2.10	1.12	0.31
Fox	7.73	7.78	7.57	3.87	3.46	3.66	1.81	1.03	0.62
Lynx	9.43	10.71	10.07	4.98	5.87	5.42	2.62	1.60	0.50
Raccoon	7.37	7.78	7.57	4.31	3.65	3.98	1.50	1.28	0.56
Rhesus monkey	4.81	6.50	5.65	3.00	2.93	2.96	1.75	1.25	0.56
Opossum	4.62	6.15	5.38	2.62	3.06	2.84	1.43	1.21	0.37
Cat	5.90	7.06	6.48	3.43	3.37	3.40	1.75	1.31	0.50
Spider monkey	5.68	7.00	6.34	3.70	4.12	3.91	1.84	1.59	0.62
Java monkey	5.68	6.31	5.99	3.75	3.25	3.50	1.50	1.06	1.12
Rabbit	4.60	5.59	5.09	2.89	4.10	3.39	1.43	1.01	1.12
Agouti	6.71	6.43	6.57	3.59	3.25	3.42	1.50	1.10	0.37
Guinea-pig	2.87	4.06	3.46	1.93	2.18	2.05	1.12	0.81	0.43
Rat	2.90	4.50	3.70	1.87	2.84	2.35	1.18	0.87	0.43
Mouse	1.48	2.56	2.02	1.09	1.68	1.38	0.78	0.75	0.25
Bat	1.31	2.93	2.12	1.25	1.93	1.59	0.93	0.87	0.15

TABLE 3

Measurements of thoracic region in millimeters. Table 3 records measurements of transverse sections from the thoracic region, taken as those recorded in table 2.

ANIMAL	1. DORSO-VENTRAL DIAMETER	2. LATERAL DIAMETER	3. MEAN DIAMETER	4. THICKNESS GREY FIGURE	5. WIDTH GREY FIGURE	6. MEAN GREY FIGURE	7. WIDTH VENTRAL HORN	8. WIDTH DORSAL HORN	9. WIDTH GREY COMMISSURE.
Elephant	14.65	18.56	16.60	5.71	4.68	5.19	1.10	1.75	0.75
Horse	12.25	13.25	12.75	5.50	3.12	3.81	1.18	1.21	0.68
Ox	9.87	11.18	10.52	3.85	3.00	3.42	1.01	1.14	1.65
Bear	6.87	8.12	7.49	2.31	2.81	2.56	0.84	0.87	1.18
Hog	7.00	7.56	7.28	3.12	1.68	2.40	0.62	0.53	1.12
Man	7.31	8.50	7.90	2.68	2.43	2.55	0.93	0.50	0.37
Sheep	6.31	6.62	6.46	3.12	1.87	2.49	0.56	0.62	1.06
Kangaroo	6.81	7.15	6.98	2.87	1.56	2.21	0.50	0.56	1.31
Ape	4.15	4.68	4.41	1.75	1.18	1.46	0.32	0.87	0.56
Dog	3.76	4.59	4.17	1.62	2.09	1.85	0.65	0.53	0.56
Fox	5.15	5.06	5.10	2.18	1.25	1.71	0.46	0.26	0.23
Lynx	5.35	6.50	5.92	2.12	1.87	1.99	0.64	0.71	1.18
Raccoon	4.62	4.87	4.74	2.03	1.15	1.59	0.40	0.53	1.00
Rhesus monkey	3.37	4.93	4.15	1.37	1.43	1.40	0.40	0.62	0.93
Opossum	3.60	3.93	3.76	1.75	1.18	1.46	0.16	0.43	0.56
Cat	4.18	4.86	4.52	1.78	1.75	1.76	0.50	0.62	0.56
Spider monkey	4.12	4.12	4.12	2.31	1.18	1.74	0.28	0.43	1.12
Java monkey	3.71	3.71	3.71	1.96	0.68	1.32	0.37	0.25	1.37
Rabbit	3.84	4.53	4.18	1.93	1.62	1.77	0.64	0.56	0.75
Agouti	5.12	5.37	5.24	2.31	1.18	1.74	0.50	0.56	0.43
Guinea-pig	2.78	2.87	2.82	1.78	1.12	1.45	0.45	0.65	0.31
Rat	2.81	2.62	2.71	1.75	0.87	1.31	0.25	0.34	0.37
Mouse	1.31	1.56	1.43	0.84	0.68	0.76	0.28	0.43	0.37
Bat	1.28	1.59	1.43	1.00	1.25	1.12	0.31	0.71	0.25

TABLE 4

Measurements of lumbar region in millimeters. Table 4 records measurements of transverse sections from the lumbar region, taken as those recorded in table 2.

ANIMAL	1. DORSO-VENTRAL DIAMETER	2. LATERAL DIAMETER	3. MEAN DIAMETER	4. THICKNESS GREY FIGURE	5. WIDTH GREY FIGURE	6. MEAN GREY FIGURE	7. WIDTH VENTRAL HORN	8. WIDTH DORSAL HORN	9. WIDTH GREY COMMISSURE
Horse	13.12	21.71	17.41	7.51	10.90	9.21	5.31	3.71	0.50
Ox	9.18	16.00	12.59	5.84	9.00	7.42	3.75	3.37	0.50
Bear	8.93	10.46	9.69	5.00	5.87	5.43	2.83	1.65	0.75
Hog	7.56	9.56	8.56	3.68	4.75	4.21	1.62	1.40	0.68
Man	8.53	9.50	9.01	4.93	5.37	5.15	2.50	1.81	0.62
Sheep	7.29	10.31	8.80	4.37	5.50	4.93	2.71	2.10	0.62
Kangaroo	8.45	10.12	9.28	4.65	4.25	4.45	2.65	2.00	0.56
Ape	4.92	6.28	5.60	3.00	4.25	3.67	1.90	1.43	0.37
Dog	4.75	6.34	5.54	3.21	4.06	3.63	2.12	1.32	0.50
Fox	6.31	7.12	6.71	3.81	3.81	3.81	1.68	1.18	0.56
Lynx	7.81	9.65	8.73	5.12	5.78	5.45	2.45	1.67	0.33
Raccoon	6.21	6.81	6.51	3.71	4.50	4.10	2.09	1.43	0.71
Rhesus monkey	4.50	5.81	5.15	3.06	3.37	3.21	1.65	1.25	0.50
Opossum	4.51	5.56	5.03	2.93	3.12	3.02	1.76	1.46	0.71
Cat	5.31	6.43	5.87	3.43	3.50	3.46	1.75	1.43	0.37
Spider monkey	5.46	5.56	5.51	3.50	3.87	3.68	1.93	1.78	0.62
Java monkey	4.75	5.75	5.25	3.62	4.06	3.84	1.87	1.37	0.87
Rabbit	4.02	6.14	5.08	2.65	4.12	3.38	1.89	1.25	0.56
Agouti	5.90	6.87	6.38	3.75	5.06	4.40	2.37	1.75	0.75
Guinea-pig	2.85	3.87	3.36	1.96	2.37	2.16	1.16	1.15	0.31
Rat	2.59	4.31	3.45	1.71	2.87	2.29	1.31	0.87	0.35
Mouse	1.45	2.12	1.78	1.03	1.37	1.20	0.65	0.60	0.35
Bat	1.31	2.25	1.78	1.12	1.56	1.34	0.75	0.81	0.25

TABLE 3

Measurements of thoracic region in millimeters. Table 3 records measurements of transverse sections from the thoracic region, taken as those recorded in table 2.

ANIMAL	1. DORSO-VENTRAL DIAMETER	2. LATERAL DIAMETER	3. MEAN DIAMETER	4. THICKNESS GREY FIGURE	5. WIDTH GREY FIGURE	6. MEAN GREY FIGURE	7. WIDTH VENTRAL HORN	8. WIDTH DORSAL HORN	9. WIDTH GREY COMMISSURE.
Elephant	14.65	18.56	16.60	5.71	4.68	5.19	1.10	1.75	0.75
Horse	12.25	13.25	12.75	5.50	3.12	3.81	1.18	1.21	0.68
Ox	9.87	11.18	10.52	3.85	3.00	3.42	1.01	1.14	1.65
Bear	6.87	8.12	7.49	2.31	2.81	2.56	0.84	0.87	1.18
Hog	7.00	7.56	7.28	3.12	1.68	2.40	0.62	0.53	1.12
Man	7.31	8.50	7.90	2.68	2.43	2.55	0.93	0.50	0.37
Sheep	6.31	6.62	6.46	3.12	1.87	2.49	0.56	0.62	1.06
Kangaroo	6.81	7.15	6.98	2.87	1.56	2.21	0.50	0.56	1.31
Ape	4.15	4.68	4.41	1.75	1.18	1.46	0.32	0.87	0.56
Dog	3.76	4.59	4.17	1.62	2.09	1.85	0.65	0.53	0.56
Fox	5.15	5.06	5.10	2.18	1.25	1.71	0.46	0.26	0.23
Lynx	5.35	6.50	5.92	2.12	1.87	1.99	0.64	0.71	1.18
Raccoon	4.62	4.87	4.74	2.03	1.15	1.59	0.40	0.53	1.00
Rhesus monkey	3.37	4.93	4.15	1.37	1.43	1.40	0.40	0.62	0.93
Opossum	3.60	3.93	3.76	1.75	1.18	1.46	0.16	0.43	0.56
Cat	4.18	4.86	4.52	1.78	1.75	1.76	0.50	0.62	0.56
Spider monkey	4.12	4.12	4.12	2.31	1.18	1.74	0.28	0.43	1.12
Java monkey	3.71	3.71	3.71	1.96	0.68	1.32	0.37	0.25	1.37
Rabbit	3.84	4.53	4.18	1.93	1.62	1.77	0.64	0.56	0.75
Agouti	5.12	5.37	5.24	2.31	1.18	1.74	0.50	0.56	0.43
Guinea-pig	2.78	2.87	2.82	1.78	1.12	1.45	0.45	0.65	0.31
Rat	2.81	2.62	2.71	1.75	0.87	1.31	0.25	0.34	0.37
Mouse	1.31	1.56	1.43	0.84	0.68	0.76	0.28	0.43	0.37
Bat	1.28	1.59	1.43	1.00	1.25	1.12	0.31	0.71	0.25

TABLE 4

Measurements of lumbar region in millimeters. Table 4 records measurements of transverse sections from the lumbar region, taken as those recorded in table 2.

ANIMAL	1. DORSO-VENTRAL DIAMETER	2. LATERAL DIAMETER	3. MEAN DIAMETER	4. THICKNESS GREY FIGURE	5. WIDTH GREY FIGURE	6. MEAN GREY FIGURE	7. WIDTH VENTRAL HORN	8. WIDTH DORSAL HORN	9. WIDTH GREY COMMISSURE
Horse	13.12	21.71	17.41	7.51	10.90	9.21	5.31	3.71	0.50
Ox	9.18	16.00	12.59	5.84	9.00	7.42	3.75	3.37	0.50
Bear	8.93	10.46	9.69	5.00	5.87	5.43	2.83	1.65	0.75
Hog	7.56	9.56	8.56	3.68	4.75	4.21	1.62	1.40	0.68
Man	8.53	9.50	9.01	4.93	5.37	5.15	2.50	1.81	0.62
Sheep	7.29	10.31	8.80	4.37	5.50	4.93	2.71	2.10	0.62
Kangaroo	8.45	10.12	9.28	4.65	4.25	4.45	2.65	2.00	0.56
Ape	4.92	6.28	5.60	3.00	4.25	3.67	1.90	1.43	0.37
Dog	4.75	6.34	5.54	3.21	4.06	3.63	2.12	1.32	0.50
Fox	6.31	7.12	6.71	3.81	3.81	3.81	1.68	1.18	0.56
Lynx	7.81	9.65	8.73	5.12	5.78	5.45	2.45	1.67	0.33
Raccoon	6.21	6.81	6.51	3.71	4.50	4.10	2.09	1.43	0.71
Rhesus monkey	4.50	5.81	5.15	3.06	3.37	3.21	1.65	1.25	0.50
Opossum	4.51	5.56	5.03	2.93	3.12	3.02	1.76	1.46	0.71
Cat	5.31	6.43	5.87	3.43	3.50	3.46	1.75	1.43	0.37
Spider monkey	5.46	5.56	5.51	3.50	3.87	3.68	1.93	1.78	0.62
Java monkey	4.75	5.75	5.25	3.62	4.06	3.84	1.87	1.37	0.87
Rabbit	4.02	6.14	5.08	2.65	4.12	3.38	1.89	1.25	0.56
Agouti	5.90	6.87	6.38	3.75	5.06	4.40	2.37	1.75	0.75
Guinea-pig	2.85	3.87	3.36	1.96	2.37	2.16	1.16	1.15	0.31
Rat	2.59	4.31	3.45	1.71	2.87	2.29	1.31	0.87	0.35
Mouse	1.45	2.12	1.78	1.03	1.37	1.20	0.65	0.60	0.35
Bat	1.31	2.25	1.78	1.12	1.56	1.34	0.75	0.81	0.25

OBSERVATIONS

Common structures

In glancing over the drawings, one of the first things which attracts attention is the marked similarity of form throughout the series. Each cord is possessed of bilateral symmetry and presents a grey figure in the shape of the letter *H*, at times considerably modified. Each half of the grey figure of the cord has the ventral and dorsal horn, the gelatinous substance of Rolando being found at the apex of the latter. The two sides of the grey figures are connected by a commissure in which is a central canal surrounded by a homogeneous substance (central gelatinous substance) similar in structure to the gelatinous substance of Rolando. The white substance surrounding the grey is divided into a dorsal and a ventro-lateral funiculus by the more or less well marked dorso-lateral sulcus, the line of ingrowth of the dorsal root. The dorso-intermediate sulcus provides an interesting comparison which will be mentioned when the dorsal funiculus is considered. Each section shows a ventral median fissure but not all, in Weigert sections at least, presents a dorsal median septum. The reticular formation, present in all, varies considerably in amount as the drawings show.

Diameters

Text-books on neurology state that the human spinal cord in each region has a lateral diameter greater than the dorso-ventral. Authorities agree that the greatest difference in these diameters, or in other words, the portion of the cord most flattened dorsoventrally, is the cervical region. Cunningham '09) states that the lumbar region is more nearly circular than the thoracic. Piersol ('10) on the other hand, gives the lumbar region as being more flattened than the thoracic. The measurements for man here given agree with those of Cunningham. However measurements taken from several other specimens in this laboratory agree more nearly with Piersol.

From table 5, which records in the form of a ratio the relative amount of flattening in each region, it is seen that the bat has a cord more flatttened in its cervical region than any other animal in the series here studied. This may be accounted for in part by the extensive innervation required by the greatly developed wing musculature.

The thoracic region, in general for all the spinal cords, is flattened dorso-ventrally. In most cases the flattening is much less than in either the cervical or the lumbar region. The cords of the agouti, lynx, and rhesus monkey are peculiar in that they

TABLE 5

Ratio of dorso-ventral to lateral diameter. Table 5 gives the ratios of the dorso-ventral to the lateral diameter obtained by dividing the figures in column 2, tables 2, 3, and 4 by those in column 1 of the same tables. That is to say, the dorso-ventral diameter is to the lateral diameter as 1 is to the figures here recorded. In each column the animals are arranged in the order of the dorso-ventral flattening of the regions of their spinal cords, those showing the greater dorso-ventral flattening being placed first. The ratio for the lumbar region of the elephant is obtained from diameters given by Kopsch, as quoted from Hardesty.

CERVICAL 1		THORACIC 2		LUMBAR 3	
Bat	2.23	Rhesus monkey	1.46	Ox	1.74
Elephant	1.74	Elephant	1.26	Bat	1.71
Horse	1.73	Bat	1.24	Rat	1.66
Mouse	1.72	Dog	1.22	Horse	1.65
Ox	1.69	Lynx	1.21	Rabbit	1.52
Rat	1.55	Mouse	1.19	Elephant	1.52
Man	1.54	Bear	1.18	Mouse	1.46
Dog	1.49	Rabbit	1.17	Sheep	1.41
Guinea-pig	1.41	Man	1.16	Guinea-pig	1.35
Rhesus monkey	1.35	Cat	1.16	Dog	1.33
Opossum	1.33	Ox	1.13	Rhesus monkey	1.29
Sheep	1.25	Ape	1.12	Ape	1.27
Spider monkey	1.23	Opossum	1.09	Hog	1.26
Bear	1.23	Hog	1.08	Lynx	1.23
Rabbit	1.21	Horse	1.08	Opossum	1.23
Cat	1.19	Raccoon	1.05	Cat	1.21
Kangaroo	1.17	Kangaroo	1.04	Java monkey	1.21
Ape	1.16	Agouti	1.04	Kangaroo	1.19
Lynx	1.13	Sheep	1.04	Bear	1.17
Hog	1.13	Guinea-pig	1.01	Agouti	1.16
Java monkey	1.11	Spider monkey	1.00	Fox	1.12
Fox	1.05	Java monkey	1.00	Man	1.11
Raccoon	1.05	Fox	0.98	Raccoon	1.09
Agouti	0.95	Rat	0.90	Spider monkey	1.01

possess greater flattening in the thoracic than in the cervical region, the sections of which latter are approximately circular. Man, bear, and rhesus monkey stand alone in having a cord in which the thoracic region possesses more dorso-ventral flattening than does the lumbar region.

In about half the mammals of the series, including man, the cervical region of the cords shows a greater dorso-ventral flattening than the lumbar region. In the other half the order is reversed, the greater flattening occurring not in the cervical but in the lumbar region. Chief among this latter number are the sheep, rabbit, hog and Java monkey which, as will be noted, have relatively a very small dorsal funiculus. While on the other hand the bat, mouse, and man have greatly flattened cervical regions and very large dorsal funiculi (column 4, table 8b). The shape of the cords in the series varies to such an extent in each region that it is difficult to say that any given cord is of a predominately rounded or flattened form throughout its length. However, from data here given we may say the bat and elephant are types of dorso-ventrally flattened cords while the fox possesses a cord of rounded form.

Enlargements and total area

As is well known the cervical and lumbar enlargements are the result of a response to the increased demand for innervation made by the extremities. Furthermore, four-footed animals with approximately equally developed extremities have the area of the cervical enlargement greater than that of the lumbar, due largely to the fact that the cervical region is concerned with the innervation of the tissues of the thorax in addition to those of the upper extremity as well as to the fact that this region carries all the fibers connecting the regions below it with the brain. The kangaroo, with its very small anterior extremities, has a lumbar enlargement the total area of which in transverse section is 13.99 sq. mm. greater than the total area of the section of its cervical enlargement (column 1, table 6, and fig. 8, *C* and *L*).

Schmidt ('08) states that the Dipus (laculus), a kangaroo-like rodent, has, notwithstanding its relatively small anterior extremities, a cervical enlargement which exceeds the lumbar. He suggests that the size of the cervical enlargement may be due to the relatively more active anterior extremity.

A very striking illustration of the significance of the enlargements is given by Streeter ('03) in a description of the ostrich cord. The ostrich, according to Streeter, has an insignificant cervical enlargement to correspond with the almost functionless wings. The 'lumbar brain,' on the other hand, extends through eleven segments and its transverse section has an average area of 38.5 sq. mm., which is 20.3 sq. mm. greater than the largest area from the cervical enlargement. Hardesty ('05) finds a similar condition in the cord of the emu, a bird closely allied to the ostrich. The ostrich and emu may be taken as examples in the bird family, of a condition present in the kangaroo among mammalia.

Spitzka ('86) states that the bat has an insignificant lumbar enlargement to correspond with the diminutive posterior extremities. The specimen of bat here used (Nyctinomus brasiliensis nasutus) has a well marked enlargement in the lumbar region as well as a large cervical enlargement which furnishes innervation for its powerful wings (figs 24, *C* and *L*). Likewise, it is interesting to note, as stated by Cunningham ('09), that in the cetacea, although there are no visible hind limbs there is a well marked lumbar enlargement. In these animals, this enlargement is no doubt required by the large and powerful tail.

The grey substance

The *H* shape of the grey figure, described as characteristic of the human cord, holds, as is well known, for the great majority of mammals. In the thoracic region of the bear, rhesus monkey, cat, dog, lynx, and spider monkey the *H* is highly modified (*Th* in figs. 4, 10, 12, 14, 16, 17). In the first five animals the peculiar shape consists in a shortening or flattening of the dorsal horns and a relatively very wide grey commissure. The almost complete absence of the dorsal horns in these animals

TABLE 6

Areas of transverse sections in square millimeters. Table 6 records the total areas in square millimeters of the transverse sections from the different regions of the spinal cords of the animals given and actual areas of the portions of the transverse sections as indicated in the headings of the columns.

ANIMAL	REGION	1 TOTAL AREA	2 AREA OF GREY FIGURE	3 AREA OF DORSAL FUNICULUS	4 AREA OF ANTERO-LATERAL FUNICULUS	5 TOTAL AREA OF WHITE SUBSTANCE
Elephant	C.	429.68	74.06	100.00	255.62	355.62
	T.	224.06	16.40	40.93	166.73	207.66
	L.					
Horse	C.	262.96	44.53	47.34	171.09	218.43
	T.	131.25	14.06	15.15	102.04	117.19
	L.	233.35	62.50	51.56	119.29	170.85
Ox	C.	167.81	36.87	29.06	101.88	130.94
	T.	85.93	9.37	9.68	66.88	76.56
	L.	132.03	39.53	21.87	70.63	92.50
Bear	C.	120.15	29.92	20.70	69.53	90.23
	T.	44.03	4.92	7.57	31.54	39.11
	L.	74.60	21.56	16.64	36.40	53.04
Hog	C.	85.00	18.59	11.59	54.82	66.41
	T.	36.40	4.14	4.92	27.34	32.26
	L.	59.92	11.25	13.43	35.24	48.67
Man	C.	100.39	16.75	26.17	57.47	83.64
	T.	52.42	5.00	14.53	32.89	47.42
	L.	65.93	21.12	15.62	29.18	44.81
Sheep	C.	82.65	21.71	11.56	49.38	60.94
	T.	35.70	4.37	3.12	28.21	31.33
	L.	61.70	20.15	9.21	32.35	41.56
Kangaroo	C.	55.93	10.62	9.60	35.71	45.31
	T.	40.46	3.75	4.21	32.50	36.71
	L.	69.92	19.68	12.42	37.82	50.24
Ape	C.	41.64	10.23	8.82	22.59	31.41
	T.	16.25	1.56	3.12	11.57	14.69
	L.	26.09	10.54	4.60	10.95	15.55
Dog	C.	35.46	10.93	5.78	18.75	24.53
	T.	14.21	2.65	1.56	10.00	11.56
	L.	26.25	9.68	3.90	12.67	16.57
Fox	C.	45.15	11.79	6.25	27.11	33.36
	T.	21.40	2.26	2.03	17.11	19.14
	L.	37.18	11.71	4.68	20.79	25.47
Lynx	C.	80.37	22.03	14.06	44.30	58.36
	T.	27.89	3.20	3.20	21.49	24.69
	L.	53.90	21.25	9.29	23.36	32.65

TABLE 6—Continued

ANIMAL	REGION	1 TOTAL AREA	2 AREA OF GREY FIGURE	3 AREA OF DORSAL FUNICULUS	4 AREA OF ANTERO-LATERAL FUNICULUS	5 TOTAL AREA OF WHITE SUBSTANCE
Raccoon	C.	45.39	11.87	10.70	22.82	33.52
	T.	17.73	1.79	3.82	12.12	15.94
	L.	33.82	12.65	5.39	15.78	21.17
Rhesus monkey	C.	26.95	9.06	5.62	12.17	17.89
	T.	12.81	1.56	1.54	9.71	11.25
	L.	21.87	8.43	4.37	9.07	13.44
Opossum	C.	23.90	6.40	4.68	12.82	17.50
	T.	10.78	1.56	1.56	7.66	9.22
	L.	20.85	8.04	2.50	10.35	12.81
Cat	C.	35.31	10.56	5.70	19.05	24.75
	T.	15.15	2.10	2.93	10.12	13.05
	L.	28.20	10.46	4.92	12.82	17.74
Spider monkey	C.	32.81	12.03	6.25	14.53	20.78
	T.	13.90	2.18	3.12	8.60	11.72
	L.	25.00	10.85	4.53	9.62	14.15
Java monkey	C.	30.46	9.37	5.46	15.63	21.09
	T.	11.09	1.40	1.25	8.44	9.69
	L.	23.28	11.71	2.34	9.23	11.57
Rabbit	C.	21.32	6.40	2.81	12.11	14.92
	T.	13.59	2.50	1.56	9.53	11.09
	L.	20.62	7.81	2.57	10.24	12.81
Agouti	C.	35.00	8.20	6.71	20.09	26.80
	T.	21.87	2.65	3.59	15.63	19.22
	L.	34.21	15.31	4.92	13.98	18.90
Guinea-pig	C.	9.92	3.12	1.48	5.32	6.80
	T.	6.71	1.71	1.09	3.91	5.00
	L.	9.84	4.45	1.40	3.99	5.39
Gray rat	C.	11.32	4.06	1.79	5.47	7.26
	T.	6.09	1.87	1.01	3.21	4.22
	L.	9.37	3.82	1.40	4.15	5.55
Mouse	C.	3.98	1.87	0.63	1.48	2.11
	T.	2.03	0.78	0.31	0.94	1.25
	L.	3.43	1.56	0.70	1.17	1.87
Bat	C.	3.59	2.18	0.41	1.00	1.41
	T.	1.71	1.32	0.12	0.27	0.39
	L.	2.96	1.56	0.48	0.92	1.40

is quite striking. This condition may be interpreted as a dorso-ventral thickening and mesial fusion of the dorsal horns (posterior grey columns) since the gelatinous substance of Rolando and the dorsal horn cells are present as normally. The spider monkey (fig. 17) possesses relatively short ventral or anterior horns and this relative shortening is evident through all three regions of the cord.

In all the animals here studied, with one exception, the width or thickness of the ventral horn in the cervical region exceeds that of the dorsal horn. This exception is in the kangaroo in the cervical region of which, the caput of the dorsal horn is wider than is the ventral horn. This condition in the kangaroo is due, not to a relatively extra wide dorsal horn but to a narrow ventral horn. Because of its small anterior extremities, it is probable that cutaneous innervation may not have decreased to the same extent as the innervation required by the muscles, which receive motor or ventral root-fibers and which have atrophied through greatly lessened use. If such be the case, the retained width of the dorsal horn may be understood in that it contains the cell bodies of association and commissural neurones about which the dorsal root or sensory fibers terminate for purposes of functionally associating different levels and the two sides of the spinal cord with sensations brought into the cervical region.

The lumbar region shows throughout the series the ventral horn to be wider than the dorsal horn (columns 7 and 8, table 4). However, the average difference in the width of the two horns in the lumbar region for the series is only 0.52 mm. while in the cervical region the average difference is 0.64 mm., the ventral horn being the wider.

The difference in width of the dorsal and ventral horns is in the thoracic region very much less than in either of the other two regions (columns 7 and 8, table 3). In most cases the dorsal horn is somewhat the wider. This is what we should expect since in the thoracic region the musculature is lessened in amount to an extent greater than is the sensory area decreased.

The dorso-ventral width of the grey commissure as taken through the central canal (column 9, tables 2, 3, 4), varies throughout the series. The average thickness is greater in the thoracic region than in either of the other two regions, being 0.84 mm. in the thoracic, 0.61 mm. for the cervical and 0.54 mm. for the lumbar region. It is noticeably thick in the thoracic regions of the ox, bear, hog, sheep, kangaroo, fox, Java monkey, and rabbit.

Reticular formation. There is considerable variation in the amount of reticular formation as shown in the figures. This reticular network is believed to be formed, at least in part, by a dispersion of the lateral portions of the grey figure (1) by bundles of longitudinally coursing association fibers (fasciculi proprii), (2) by fibers passing out of the grey figure into the white substance and (3) by the fibers from the crossed pyramidal tracts leaving the lateral funiculus and entering the grey figure to terminate about ventral horn cells. However, the lateral pyramidal tract may have little to do with it for the animals which have their pyramidal tract in the dorsal funiculus have the reticular formation as well, often better, marked than do animals which have the pyramidal tract in the lateral funiculus.

Nucleus dorsalis. A nucleus dorsalis (Clarke's column) is well marked in the thoracic region of by far the greater number of animals here studied. In the following six mammals, kangaroo, opossum, agouti, guinea-pig, rat, and mouse the nucleus is not clearly defined. As will be mentioned, the pyramidal tract in each of these animals courses, probably in the dorsal funiculus and it may be that the dorsal position of this tract is in some way associated with the modified appearance of the nucleus dorsalis. These observations are based on the study of Weigert sections in which the cell-bodies are not stained, but the position and usually a very good outline of the cell-body may be seen.

Proportion of grey substance to white. An idea of the relative amount of grey substance as compared with white in the spinal cord is best obtained from a study of the ratios of the absolute areas of the two. Table 7 gives such a ratio for the three regions of the cord of each animal. The area of the grey figure is to the total area of the white substance as 1 is to the figure given in the table. All of the spinal cords, with the exception of the mouse and bat, show the lumbar region to contain the largest relative amount of grey substance, while the thoracic contains the smallest relative amount, in each animal. An average of the ratios in the three regions is valuable since it provides a comparison of the relative amounts of white and grey substance through, what we may consider, the entire cord. The average of the ratios in the three regions emphasizes the well known fact that, in general, the smaller the animal, the greater is the proportion of grey substance to white. A glance at the drawings of the cervical and thoracic regions of the elephant (fig. 1, *C* and *Th*) and the corresponding regions of the bat (fig. 24, *C* and *Th*) show the relatively high proportion of grey substance in the smaller animals.

TABLE 7

Ratio of area of grey substance to area of white substance. Table 7 records the ratios of grey substance to white substance obtained by dividing the figures in column 2 of table 6 into those of column 5, table 6, that is to say, the area of grey substance is to the area of white substance as 1 is to the figures recorded in columns 1, 2, and 3.

ANIMAL	CERVICAL 1	THORACIC 2	LUMBAR 3	AVERAGE 4
Elephant	4.8	12.6		
Horse	4.9	8.3	2.7	5.2
Ox	3.6	6.1	2.3	4.0
Bear	3.0	7.9	2.4	4.4
Hog	3.6	7.8	4.3	5.2
Man	5.0	9.5	2.1	5.5
Sheep	2.8	7.2	2.1	4.0
Kangaroo	4.3	9.8	2.6	5.5
Ape	3.1	9.4	1.5	4.6
Dog	2.2	4.3	1.7	2.7
Fox	2.8	8.5	2.2	4.5
Lynx	2.6	7.7	1.5	3.9
Raccoon	2.8	8.9	1.7	4.4
Rhesus monkey	2.0	7.2	1.6	3.6
Opossum	2.7	5.9	1.6	3.4
Cat	2.3	6.2	1.7	3.4
Spider monkey	1.7	5.4	1.3	2.8
Java monkey	2.3	6.9	0.9	3.3
Rabbit	2.3	4.4	1.6	2.7
Agouti	3.3	7.3	1.2	3.9
Guinea-pig	2.2	2.9	1.2	2.1
Rat	1.8	2.3	1.5	1.8
Mouse	1.1	1.6	1.2	1.3
Bat	0.6	0.3	0.9	0.6

White substance

Dorso-intermediate sulcus. In the kangaroo, raccoon, opossum, and Java monkey, a dorso-intermediate sulcus is clearly present in all three regions (figs. 8, 13, 15 and 18). In a much larger number of species it is clearly evident only in the cervical region, man being among this number. In some animals, the ox, sheep and dog, for example, in Weigert preparations, it is not to be seen in any of the regions. In most of the sections, considerable difference is noted between the areas of white substance on either side of this sulcus. The area nearest the dorsal median septum, corresponding to the fasciculus gracilis in man, is composed of relatively small, closely packed axones which give it a darkened appearance in transverse sections stained by the Weigert method. The lateral area which corresponds to man's fasciculus cuneatus, is composed of relatively larger axones. Singer ('81), who describes the origin and position of the fasciculus gracilis in the dog, shows in his drawings no septum between it and the fasciulus cuneatus. It must be that in certain animals the factors which determine whether there shall be an ingrowth of the pial connective tissue to form this sulcus are different during fetal life while the fasciculus gracilis and fasciculus cuneatus are being acquired and becoming medullated. In most cases where the sulcus is wanting, one may observe in the cervical and thoracic regions that the fibers are smaller and more closely accumulated, and that the area is darker, near the dorsal median septum than in the more lateral areas of the dorsal funiculus.

Position of pyramidal tract. Simpson ('02) describes the pyraamidal tract for the dog, cat and monkey as situated in the dorsal part of the lateral funiculus. The guinea-pig and mouse, according to Reverly and Simpson ('10), who confirm the earlier work of Von Bechterew and Von Lenhossek, have the pyramidal tract in the dorsal funiculus. King ('10) has traced the pyramidal tract of the rat into the dorsal funiculus. Spitzka ('86) states that the sheep and ox have no fibers, to be seen macroscopically, which cross from the pyramids in the medulla oblongata into the lateral funiculus. The elephant, according to Hardesty ('02), has a part at least of the pyramidal tract situated on either side of the mid-line between the dorsal and ventral lamina of the grey commissure. Believing that it corresponds to the lateral or crossed pyramidal tract in man, he has designated it 'fasciculus cerebro-spinalis internus' (fig. 1, *C* and *Th*). Burkholder ('04) describes this tract in the sheep as occupying the same position as in the elephant and has termed it the 'fasciculus cerebro-spinalis internus' after Hardesty. King and Simpson ('10) state that the pyramidal fibers for the sheep are situated in the reticular formation in the lateral aspect of the dorsal horn. The specimen of sheep here studied, as well as the ox, presents in all three regions a structure identical in position to that described by Burkholder (figs. 3 and 7, *C*, *Th* and *L*). Symington ('08) states that the kangaroo has the pyramidal tract in the dorsal funiculus and the rabbit has the tract in the lateral funiculus.

I have compared sections through the pyramidal decussation in the medulla of the agouti and opossum with those of the rat, mouse and kangaroo, and am of the opinion that the pyramidal tract in the former animals, as well as in the latter, is situated in the dorsal funiculus. The agouti, like the rat, mouse and guinea-pig, is a rodent, while the opossum, being a marsupial, is related to the kangaroo. From an examination of sections through the medulla of the raccoon and of the fox, the pyramidal fibers appear to course in the reticular formation. However, the experimental method is the only trustworthy one for determining the position of any fiber tract.

Comparison of funiculi. As is to be expected, all of the cords here considered have, in each region, a dorsal funiculus which is exceeded in actual area in transverse section by the ventro-lateral funiculus (table 6). The comparative size of the funiculi can be best expressed in the form of a ratio. Table 8 (*a* and *b*) record such ratios for each region, obtained by dividing the area of the ventro-lateral funiculus by that of the dorsal funiculus. It is clear that the higher the ratio, the smaller relatively is the dorsal funiculus. For example, table 8a, column 4, gives man as having the lowest average ratio, 2.10, which means that the average size of the ventro-lateral funiculus for the three regions is 2.10 times the size of the dorsal funiculus for the three regions. The fox with the highest average ratio, 5.73, shows therefore relatively the smallest dorsal funiculus of the series.

While the human cord does not show the largest relative size of the dorsal funiculus in either the cervical or the lumbar region, being surpassed in the former by the raccoon and rhesus monkey, in the latter by mouse and rhesus monkey, yet the average of the three regions places man first. In other words, all the other

TABLE 8 a

Ratios of dorsal funiculus to ventro-lateral funiculus. Table 8a has been computed from data in table 6, by dividing the figures in column 4 by those in column 3, table 6. In other words, the dorsal funiculus is to the ventro-lateral funiculus as 1 is to the figures in columns 1, 2 and 3 below. Column 4 records the average ratios of 1, 2 and 3. The animals are arranged according to body weight.

ANIMAL	CERVICAL 1	THORACIC 2	LUMBAR 3	AVERAGE RATIO 4
Elephant	2.55	4.07		
Horse	3.61	6.73	2.31	2.96
Ox	3.50	6.90	3.22	4.54
Bear	3.35	4.16	2.18	3.23
Hog	4.72	5.55	2.62	4.29
Man	2.19	2.26	1.86	2.10
Sheep	4.27	9.04	3.51	5.60
Kangaroo	3.71	7.72	3.04	4.82
Ape	2.56	3.70	2.38	2.88
Dog	3.24	6.41	3.24	4.29
Fox	4.33	8.42	4.44	5.73
Lynx	3.15	6.71	2.51	4.12
Raccoon	2.13	3.17	2.92	2.74
Rhesus monkey	2.18	7.03	1.75	3.65
Opossum	2.52	4.91	4.12	3.85
Cat	3.34	3.45	2.60	3.13
Spider monkey	2.32	2.75	2.12	2.39
Java monkey	2.88	6.75	3.94	4.52
Rabbit	4.30	6.10	3.98	4.79
Agouti	2.99	4.35	2.84	3.39
Guinea-pig	3.59	3.58	3.58	3.58
Rat	3.05	3.17	2.90	3.04
Mouse	2.34	3.03	1.67	2.34
Bat	2.43	2.27	1.91	2.20

cords in the series have average dorsal funiculi smaller in proportion to the ventro-lateral funiculi than does the human spinal cord. The dorsal funiculus in man is made up, in large part, of ascending axones of spinal ganglion neurones, a large proportion of which connect the cord with the encephalon. The latter reaches its highest development in man and the dorsal funiculus is correspondingly increased in size. We might expect the cervical region in man especially to show a larger ratio for the dorsal funiculus than does the thoracic or lumbar region since

TABLE 8 b

Ratios dorsal funiculus to ventro-lateral funiculus. Table 8b records the same data as table 8a but with the animals arranged according to the relative size of the dorsal funiculus in each region of the cord instead of according to body weight.

CERVICAL 1		THORACIC 2		LUMBAR 3		AVERAGE 4	
Raccoon	2.13	Man	2.26	Mouse	1.67	Man	2.10
Rhesus monkey	2.18	Bat	2.27	Rhesus monkey	1.76	Bat	2.20
Man	2.19	Spider monkey	2.75	Man	1.86	Mouse	2.34
Spider monkey	2.32	Mouse	3.03	Bat	1.91	Spider monkey	2.39
Mouse	2.34	Raccoon	3.17	Spider monkey	2.12	Raccoon	2.75
Bat	2.43	Rat	3.17	Bear	2.18	Ape	2.88
Opossum	2.52	Cat	3.45	Horse	2.31	Horse	2.95
Elephant	2.55	Guinea-pig	3.58	Ape	2.38	Rat	3.04
Ape	2.56	Ape	3.70	Lynx	2.51	Cat	3.13
Java monkey	2.88	Elephant	4.07	Cat	2.60	Bear	3.23
Agouti	2.99	Bear	4.16	Hog	2.62	Agouti	3.39
Rat	3.05	Agouti	4.35	Agouti	2.84	Guinea-pig	3.58
Lynx	3.15	Opossum	4.91	Rat	2.90	Rhesus monkey	3.65
Dog	3.24	Hog	5.55	Raccoon	2.92	Opossum	3.85
Cat	3.34	Rabbit	6.10	Kangaroo	3.04	Lynx	4.12
Bear	3.35	Dog	6.41	Ox	3.22	Dog	4.29
Ox	3.50	Lynx	6.71	Dog	3.24	Hog	4.29
Guinea-pig	3.59	Horse	6.73	Sheep	3.51	Java monkey	4.52
Horse	3.61	Java monkey	6.75	Guinea-pig	3.58	Ox	4.54
Kangaroo	3.71	Ox	6.90	Java monkey	3.94	Rabbit	4.79
Sheep	4.27	Rhesus monkey	7.03	Rabbit	3.98	Kangaroo	4.82
Rabbit	4.30	Kangaroo	7.72	Opossum	4.12	Sheep	5.60
Fox	4.33	Fox	8.42	Fox	4.44	Fox	5.73
Hog	4.72	Sheep	9.04				

the two fasciculi of which it is largely composed contain a large proportion of spino-cerebral fibers ascending from all segments of the cord and thus it must increase in size from below upward. However, column 3, table 8a, shows the lumbar region of the human cord to possess a larger relative size for the dorsal funiculus than either of the other two regions. The pyramidal tract, in the ventro-lateral funiculus, which has its maximum size in the cervical region is one of the principal factors in reducing the relative size of the dorsal funiculus in this region. Another factor in the lumbar enlargement is the large proportion of association fibers in the dorsal fasciculi proprii of the dorsal funiculus.

In those animals in which the crossed pyramidal tracts course in the dorsal, instead of in the lateral funiculus, one would expect a relatively larger area of dorsal funiculus and a resultingly smaller area in the ventro-lateral funiculus. Reference to these animals in tables 8a and 8b does not show a relatively greater area of the dorsal funiculus (smaller ratio of the ventro-lateral funiculus) to be of distinguishingly constant occurrence. In some cases, agouti, guinea-pig and rat, for example, the ratios for the cervical region are approximately the same as those for the lumbar region in spite of the fact that there are both ascending and descending fibers in the dorsal funiculus which must increase as the cord is ascended.

In all mammals, there is a decrease in the absolute area of the dorsal funiculus in passing from the lumbar to the thoracic region. The horse, ox, bear, sheep, kangaroo, hog and lynx show a very great decrease in the area of the dorsal funiculus from the lumbar to the thoracic region (table 6). The difference in the area of the ventro-lateral funiculus in the two regions of the above animals is very slight. This fact is expressed in another form in columns 2 and 3, table 8b. The horse, for example, has in the transverse section of the lumbar region a ventro-lateral funiculus 2.31 times that of the dorsal funiculus, while in the thoracic region, the ventro-lateral funiculus is 6.73 times the dorsal. It is probable that in these animals an especially large number of axones from the dorsal roots of the lumbar region extend up the cord only a short distance and then terminate around cell-bodies in the grey substance.

The ape and monkeys, as expected from their high position among mammals, show a relatively large dorsal funiculus. The spider monkey, for example, has an average ratio for the three regions of 2.39, that is to say, the dorsal funiculus of the spider monkey is only slightly less than one-half the size of the ventro-lateral. The relatively large dorsal funiculus of this animal is explained in part at least by the fact that it possesses an exceptionally long, large and specially functioning tail whose skin area must require a large additional number of ascending axones in the cord. The striking motility and functional control of this tail must mean additional and no doubt a special bundle of pyramidal axones. These latter, descending in the lateral funiculus, render the dorsal funiculus only relatively less large than it would be otherwise.

I am not able to explain why the cord of the raccoon should show such a relatively large dorsal funiculus which, in the cervical region is to the ventro-lateral funiculus as 1 is to 2.13, being relatively larger in this region than that found in any of the other animals. The upper extremities of the raccoon are somewhat less highly functional than those of the monkey, its tail is relatively no larger and but little more functional than that of the dog or fox and its pyramidal tract does not appear to course in its dorsal funiculus. The mouse and agouti have relatively large dorsal funiculi, due, at least in part, to the fact that they have the crossed pyramidal tract in this funiculus.

Column 4, table 8b, gives the fox as having an average dorsal funiculus less than one-fifth the size of the ventro-lateral. This must mean that he possesses an enormous number of association fibers in the lateral funiculus or that the spino-cerebellar fasciculi are unusually large. It is to be noted that the great variation in relative size of the two funiculi which most of the animals show throughout the three regions is not evident in the fox (table 8b). The acuteness of the fox in reflex action is proverbial and complex reflex activities are anatomically explained on the basis of abundant association fibers (fasciculi proprii). Also, for cerebral muscular control, this animal may have relatively large pyramidal fasciculi. The sheep and rabbit likewise are popularly known as reflex animals. They stand close to the fox in the small size of the dorsal funiculus as compared with the ventrolateral. It is probable that, in these animals, by far the greater number of dorsal root axones terminate in the grey substance of the cord after a comparatively short course in the dorsal funiculus, thus accounting, in large part, for the small size of the latter. Man and the monkeys, as examples of animals with a highly developed encephalon, have relatively large dorsal funiculi; while the fox, sheep, and rabbit with acute spinal reflexes have very small dorsal funiculi. The relative size of the dorsal and ventrolateral funiculi, however, may be the result of many factors of which we have considered but a few.

This investigation has been carried on under the direction of Prof. Irving Hardesty who kindly furnished much of the material. I am under obligations to him for many helpful suggestions.

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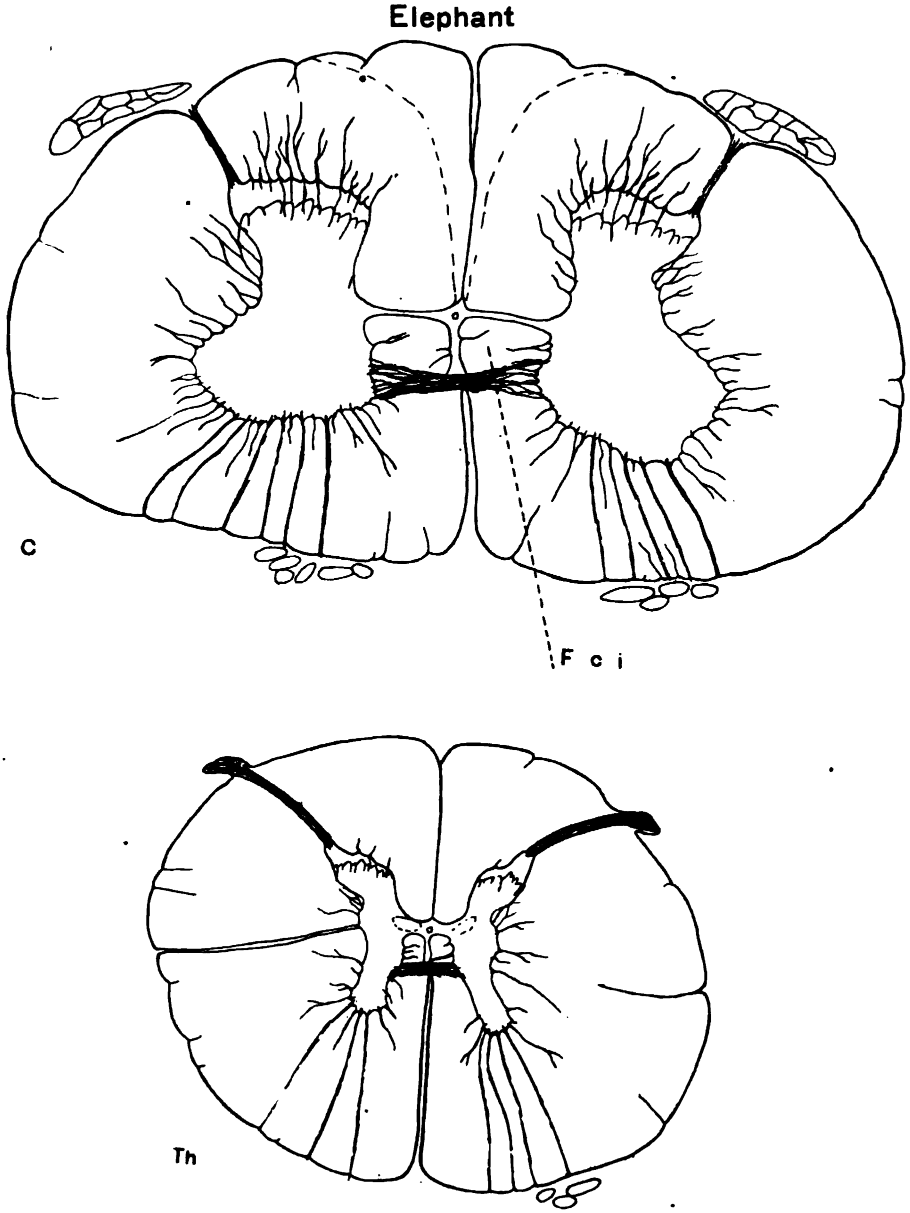
EXPLANATION OF PLATES

The plates contain figures representing outline drawings of transverse sections taken from the sixth cervical, eighth thoracic, and third lumbar segments of the spinal cords of the twenty-four mammals named. The drawings were traced from projections of the respective section with the Edinger Drawing Apparatus set for a magnification of eight diameters. They are here reduced one-half and thus are magnified four times. The letter *C* indicates the cervical region, *Th*, the thoracic, and *L*, the lumbar; *F.c.i.*, fasciculus cerebro-spinalis internus.



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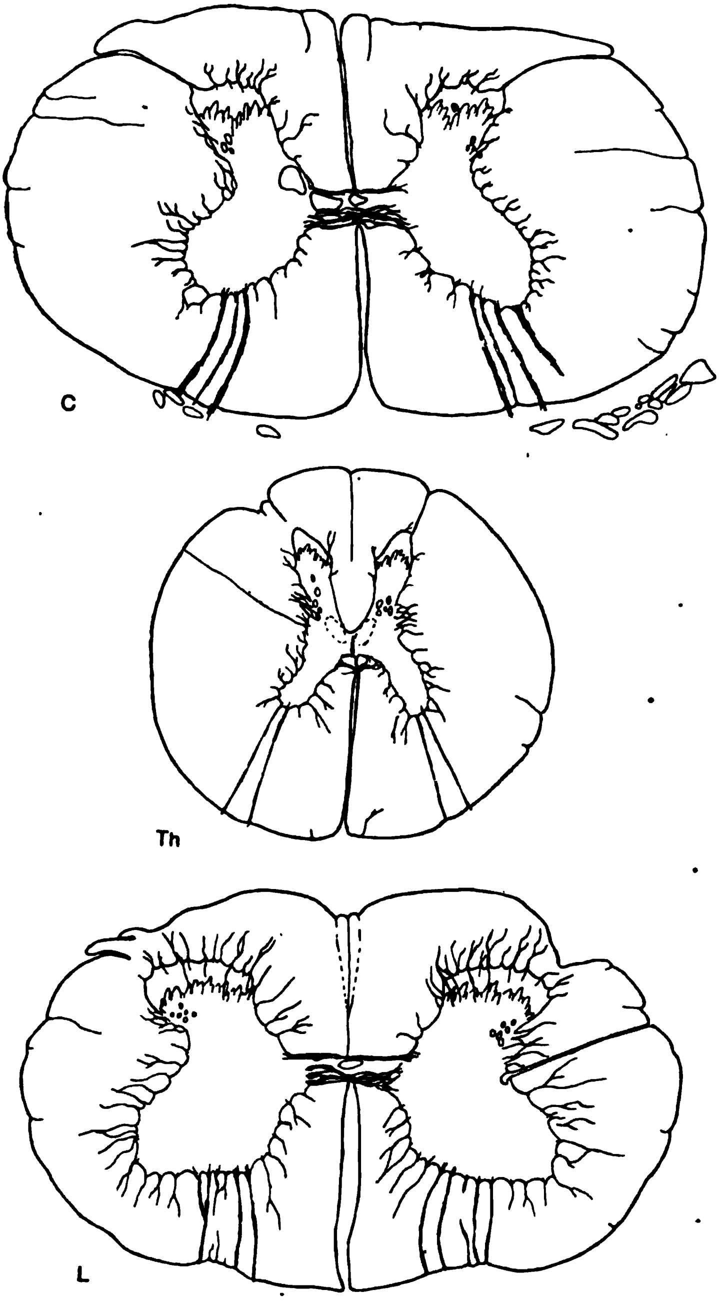
Horse



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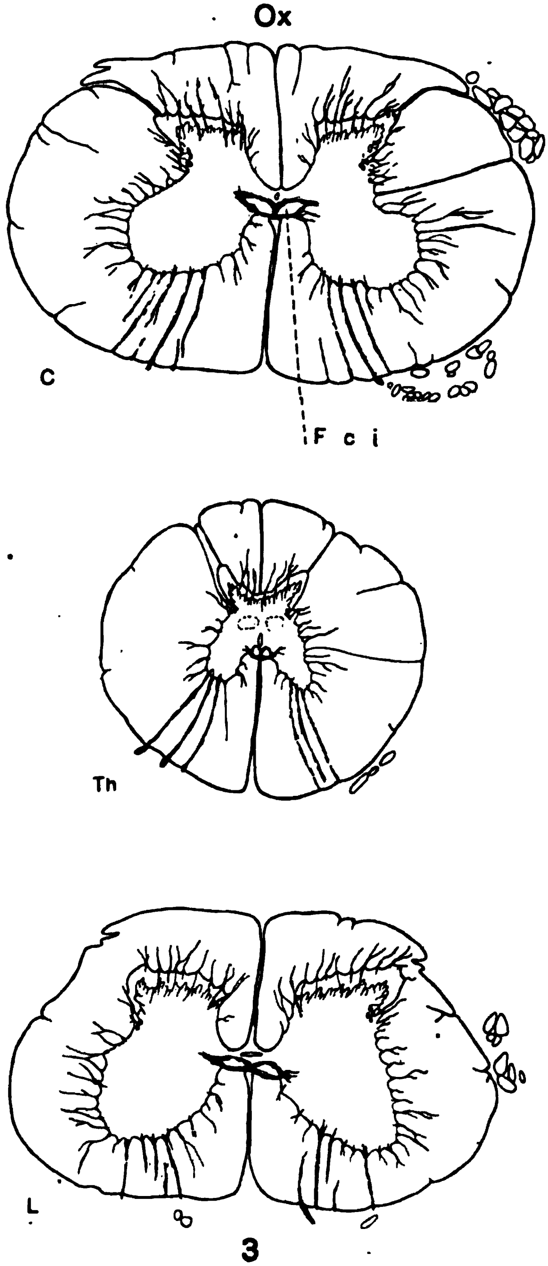

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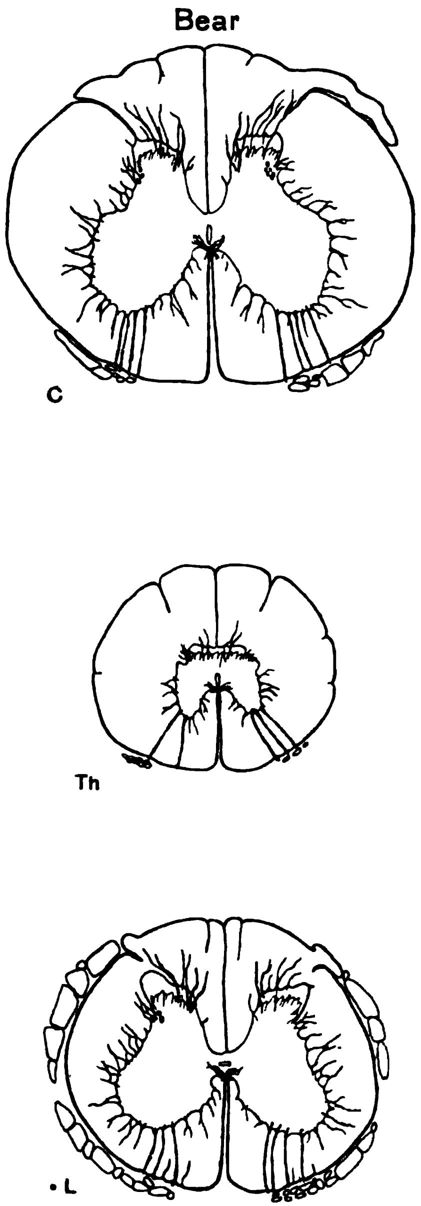

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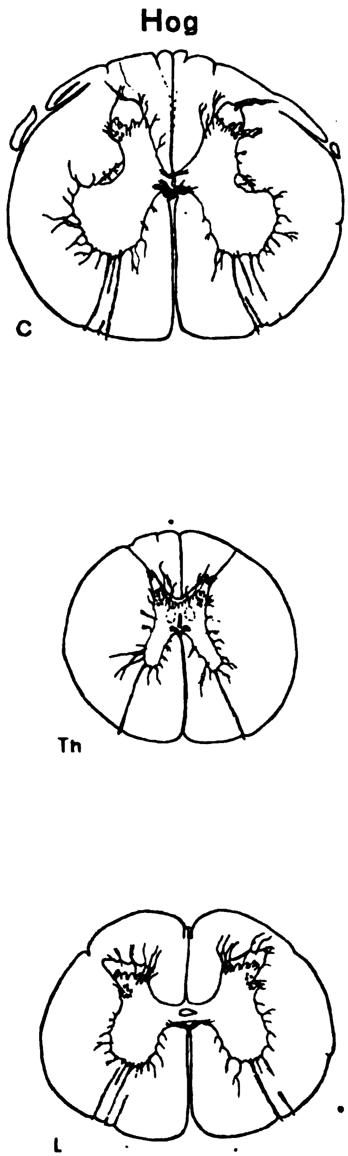

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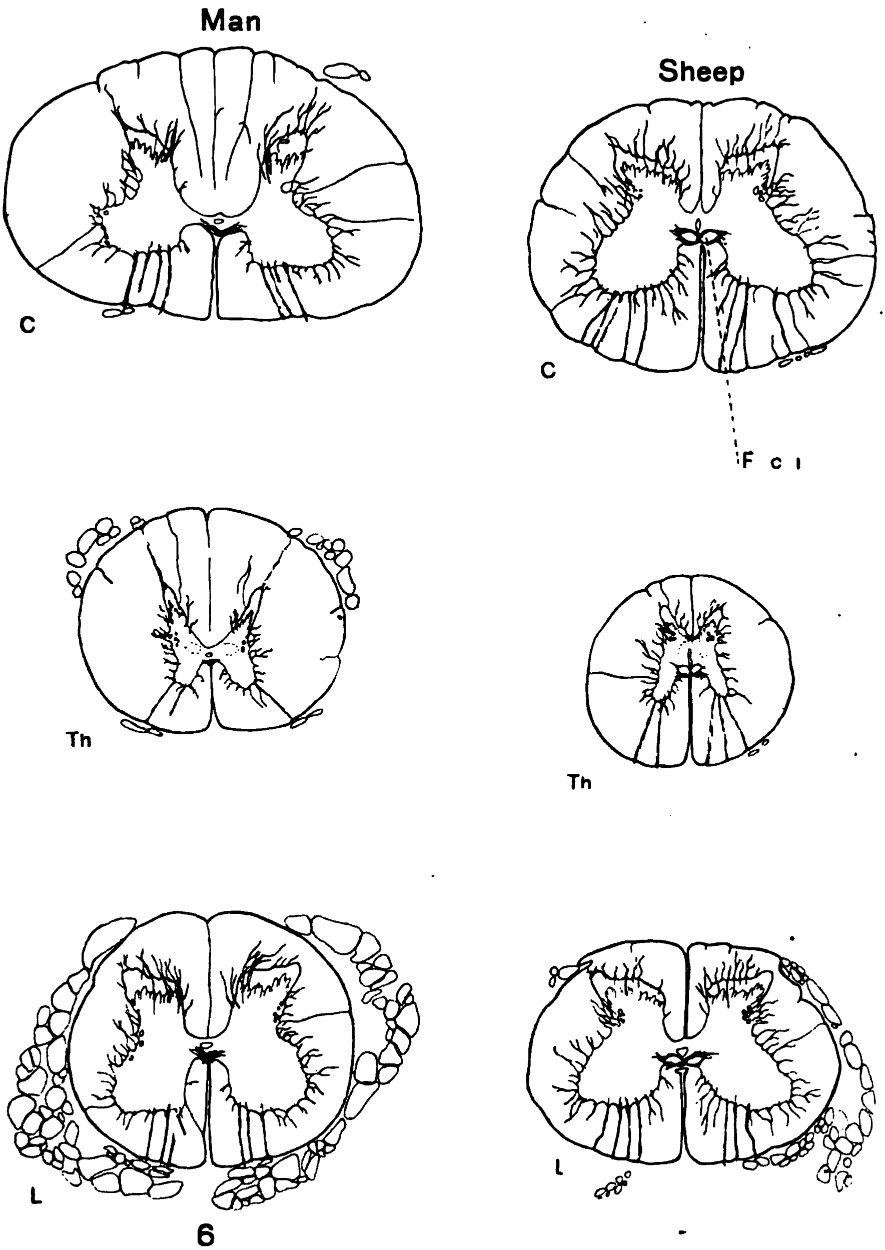
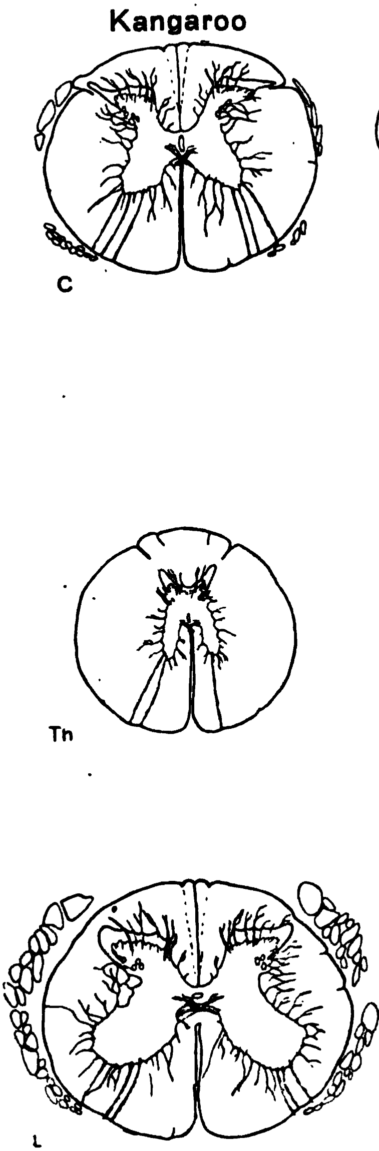
PRINCIPAL REGIONS OF SPINAL CORD
PEARL BRIGGS BULLARD

PLATE 5





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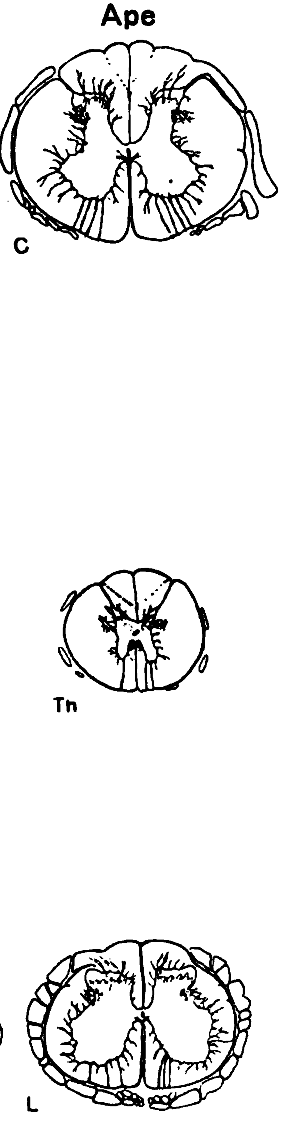

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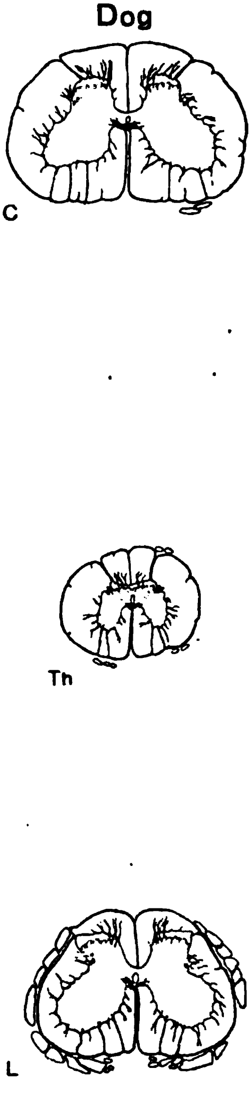

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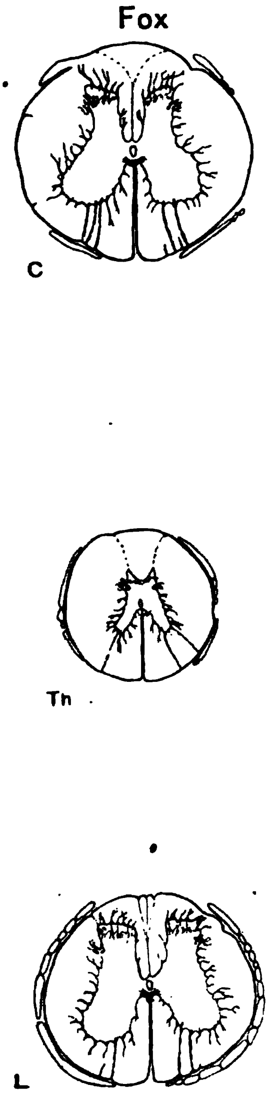

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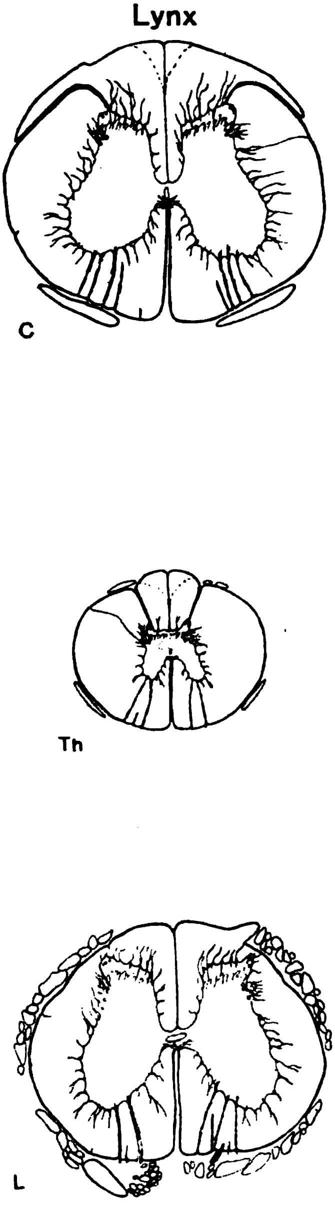

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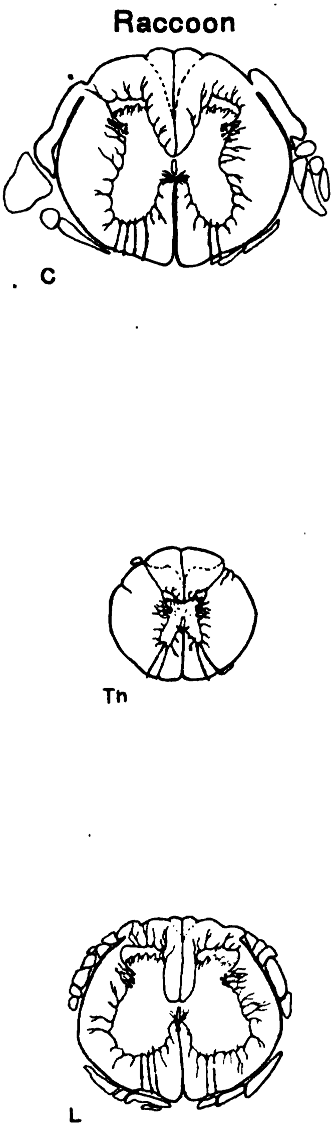

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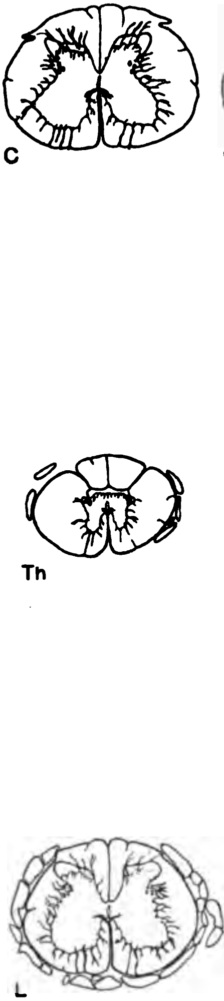
Rhesus monkey



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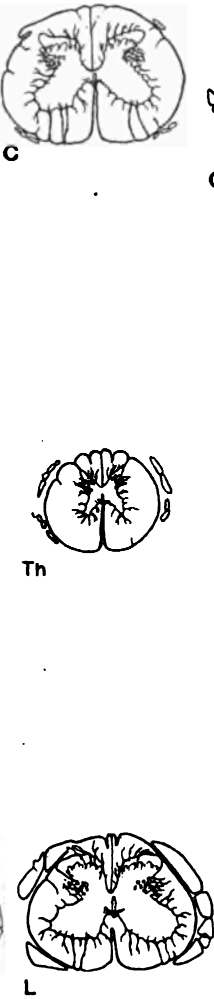
Opossum



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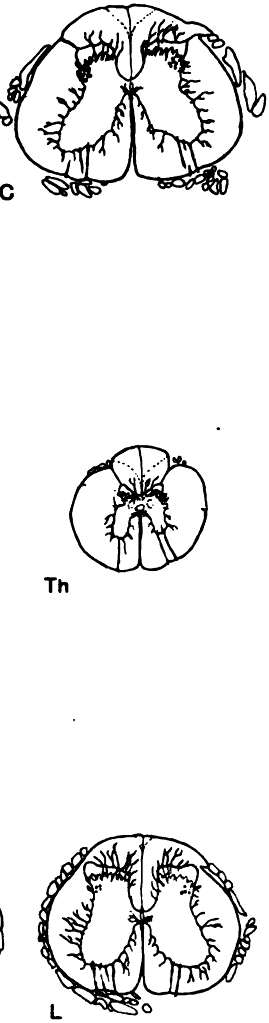
Cat



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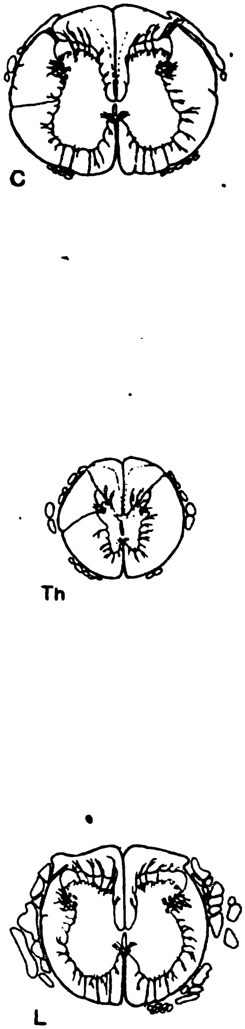
Spider monkey



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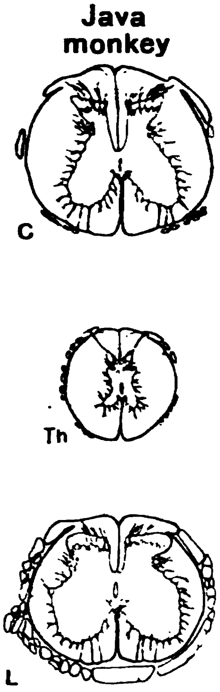

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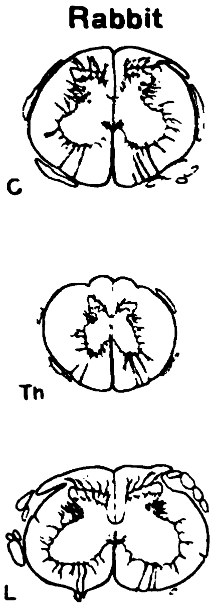

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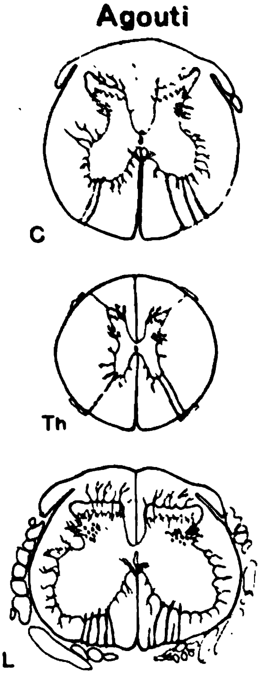

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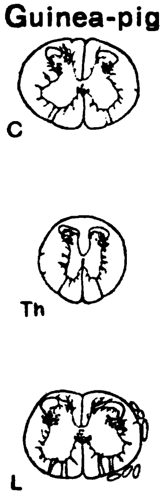

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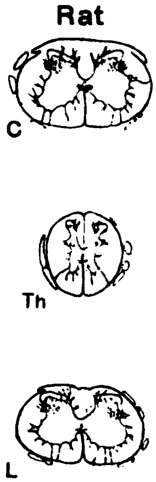

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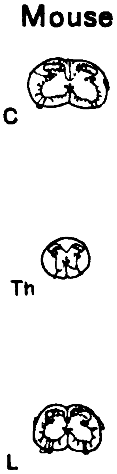

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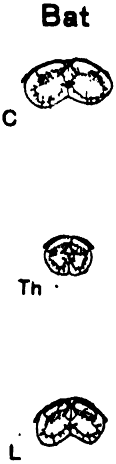

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ON THE INTERSTITIAL GRANULES AND FAT DROPLETS OF STRIATED MUSCLE

H. HAYS BULLARD

From the Anatomical Laboratory, Tulane University of Louisiana

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The granules to be found between the myo-fibrils or muscle columns of cross striated muscle, although mentioned by Henle ('41) were first described in detail by Kölliker ('57) who called them 'interstitial granules.' He applied the term to both fat droplets and true interstitial granules, the latter being of a non-fatty nature. This paper presents observations concerning the structure of striated muscle with especial reference to interstitial granules and fat droplets, including also a brief discussion of their general occurrence, chemical nature, and physiological significance. A number of important communications dealing with the interstitial granules have included a somewhat comprehensive review of the literature, namely, Retzius ('90), Arnold ('09), Holmgren ('10), Prenant ('11), and Bell ('11). As several of these papers are of recent date I have thought best to omit a chronological review and shall discuss the literature only in so far as its subject matter has a direct bearing on the topics treated in this paper.

According to Kölliker both fat droplets and true interstitial granules are of wide distribution, occurring in vertebrate muscle and also in insect muscle. A few observers have denied the existence of two general types of interstitial granules, especially in vertebrate muscle, but usually the work of Kölliker has been confirmed in this respect. My observations are in accord with those of Kölliker and I shall likewise designate the types of granules as true interstitial granules and fat granules or fat droplets.

For the present it may be said that true interstitial granules, at least for the most part, are not completely soluble in absolute alcohol and not readily stained by fat stains such as Scharlach R, while the fat droplets are easily soluble in absolute alcohol and take the fat stains. This does not necessarily mean that the true interstitial granules contain no fatty substance nor that the fat droplets are composed wholly of fatty substances. Under normal physiological conditions the muscle fibers of both skeletal muscle and cardiac muscle of vertebrates may, and usually do, contain true interstitial granules as well as fat droplets.

I. MATERIAL AND METHODS

For the most part the material was obtained from the common laboratory animals: frog, mouse, rat, rabbit, cat, dog, pigeon, and from the bat. In a few cases the nutritive condition of the animal was altered by special feeding in the laboratory. Human material was used to a considerable extent and insect muscle was also examined.

The methods used in this study have a direct bearing on the chemistry of the granules and fat droplets, and will be discussed in some detail when considering that subject. The methods may be briefly outlined as follows:

1. Examination of fresh material.
    - *a.* Preparations made without the addition of fluids.
    - *b.* Preparations mounted in normal saline solution or 1 to 5 per cent solution of potassium hydroxide.
2. Tests of solubility of interstitial granules and fat droplets with alcohol, xylol, and with ether.
3. Examination of preparations stained by various methods.
    - *a.* Simple alcoholic solutions of Scharlach R, and Sudan III.
    - *b.* Herxheimer's Scharlach R.
    - *c.* Nile blue sulphate and Nile blue chlorhydrate.
    - *d.* Cresylviolett and Cresylechtviolett.
    - *e.* The methods of Weigert, Altman, Benda, and Regaud.

Herxheimer's ('01) stain is prepared by dissolving 2 grams of Na OH in 100 cc. of 70 per cent alcohol, Scharlach R then being added to saturation. The solution is filtered into a tightly closing vessel immediately before being used. Frozen sections or teased preparations of fresh tissue, or material used after two to twelve hours fixation in 20 per cent formalin, are washed in 60 per cent alcohol, transferred to the stain for three to fifteen minutes, washed in 60 to 70 per cent alcohol twenty to thirty seconds, followed by water, and mounted in levulose or glycerine. If alcohol washing is omitted precipitates are formed. Fat droplets are stained red, true interstitial granules and the protoplasm of muscle fibers are not colored. Alum-hematoxylin or Cresylechtviolett may be used as a counter-stain for the nuclei.

Nile blue: Teased preparations or frozen sections of fresh tissue or material used after a fixation of two to twelve hours in 20 per cent formalin, are stained fifteen minutes to two hours in a saturated aqueous solution of Nile blue chlorhydrate, washed in distilled water five minutes or more, and transferred to tap water. After five minutes in tap water the preparation should assume a reddish hue. If this does not occur a slight amount of alkali may be added to the water. The preparations are mounted in either levulose, potassium acetate, or glycerine. When Nile blue sulphate is used it is necessary to add a somewhat greater amount of alkali, to the tap water. Fat droplets are stained red, purple or blue, true interstitial granules are stained blue.

Cresylviolett: Fresh material, or material after two to twelve hours fixation in formalin, is stained in a dilute aqueous solution of Cresylviolett or Cresylechtviolett for ten to twenty minutes, then washed three to five minutes in distilled water and mounted in levulose syrup. Fat droplets are colorless, or (rarely) a faint red or blue, true interstitial granules are blue.

For the details of the complicated methods of Weigert, Altmann, Benda and Regaud, the reader is referred to Encyklopädie der Mikroskopischen Technik, Berlin, Wien, 1903, and to the discussion of Fauré-Fremiet, Mayer and Schaeffer ('10). Benda's method in particular is unnecessarily complex, requiring about two weeks to prepare a specimen, and its results are not uniform. Satisfactory preparations were obtained by a modified Weigert method which may be briefly stated as follows:

Fix twenty-four hours or more in a 10 to 20 per cent solution of formalin (4 to 8 per cent formaldehyde) with the addition of 0.75 per cent sodium chloride, then mordant in 5 per cent aqueous potassium bichromate four to seven days. Imbed in paraffin and section. Stain warm two to six hours in a mixture containing hematoxylin 1 gram and 2 per cent acetic acid 200 cc. Decolorize by use of Weigert's differentiating fluid, or by dilute (0.12 per cent) potassium permanganate followed by the oxalic acid-potassium sulphite mixture of the Pal-Weigert technique. Dehydrate, clear, and mount in balsam. Or prepare paraffin sections, as above, stain in Altmann's acid fuchsin, decolorize in picric acid as used in Altmann's method and then clear and mount in balsam. The true interstitial granules are stained blue by hematoxylin or red if acid fuchsin is used.

II. NOMENCLATURE

In considering the significance of interstitial granules and fat droplets, a clear understanding of the terminology used by various authors is of importance. The true interstitial granules of Kölliker correspond to Altmann's granules or 'bioblasts,' to the 'mitochondria' of Benda, and to the 'plasmasomes' of Arnold. Granules which do not correspond to the interstitial granules but are concerned in the formation of the myo-fibrills, are also included by Altmann, Benda and Arnold, as bioblasts, mitochondria and plasmasomes. A part of the plasmasomes of Arnold, those which are not colored by basic dyes, may represent fat droplets. Benda described mitochondria in fully developed smooth muscle, but thought that they do not occur in the sarcoplasm of adult skeletal muscle, while Holmgren and others, using the technique of Benda, have described such granules in skeletal muscle fibers. The 'exoplasmic granules' (J granules and Q granules) and the 'endoplasmic granules' of Holmgren correspond to the 'Sarcosomes' of Retzius which in turn correspond to Kölliker's true interstitial granules. It is possible that Retzius and Holmgren may have occasionally confused fat droplets with sarcosomes.

Albrecht ('02) classed the interstitial granules with his 'liposomes,' which could be demonstrated in all tissues by treating fresh preparations with 5 per cent potassium hydroxide. Since some of Albrecht's liposomes in striated muscle stained by acid fuchsin while others blackened with osmic acid, it is clear that he included as liposomes both the true interstitial granules and fat droplets. Albrecht must have been mistaken in thinking that all his liposomes are seen when fresh tissues are cleared in 5 per cent potassium hydroxide. Fat droplets are brought out clearly but the granules which stain with acid fuchsin are not apparent in such preparations although they may be seen when normal saline is used instead of the alkaline solution.

Bell ('10, '11) adopted Albrecht's term 'liposome.' As designated by him, none of the liposomes stain with acid fuchsin but all of them may be colored with Herxheimer's Scharlach R and all are soluble in alcohol. He describes certain of his liposomes as faintly-refractive and is evidently of the opinion that they correspond to the faintly-refractive interstitial granules of Knoll, Kölliker and other observers.

I find that the faintly-refractive granules described by Knoll ('80, '91) in the heart and skeletal muscles of the pigeon are readily stained by the acid fuchsin method but do not stain by Herxheimer's method. These granules would thus come within the category of liposomes as the term is used by Albrecht, but they form no part of the liposomes of Bell. The faintly-refractive liposomes of the latter author are faintly-refractive fat droplets and do not correspond to the faintly-refractive granules of Knoll. Knoll himself pointed out that his faintly-refractive granules correspond to the true interstitial granules of Kölliker.

The term true interstitial granules will be used in this paper to correspond to the true interstitial granules of Kölliker which as previously mentioned include a part of the bodies described by Altmann, Benda, and Arnold respectively, as bioblasts, mitochondria and plasmasomes.

The term 'fat' is here used to include lipoids and cholesterin compounds as well as the fatty acids and their glycerin esters.

III. RELATION OF INTERSTITIAL GRANULES AND FAT DROPLETS TO COLOR AND STRUCTURE OF MUSCLE

a. Light and dark muscle fibers

Krause ('64) found that the fibers of the red muscles of the rabbit contain more interstitial granules than are present in the fibers of white or pale muscles. Grützner ('84) described two types of fibers in human muscles, cloudy or dark and pale or white. He found that all human muscles contain both types of fibers and believed that dark fibers give macroscopically the red appearance to muscles while light fibers correspond to white or pale muscles.

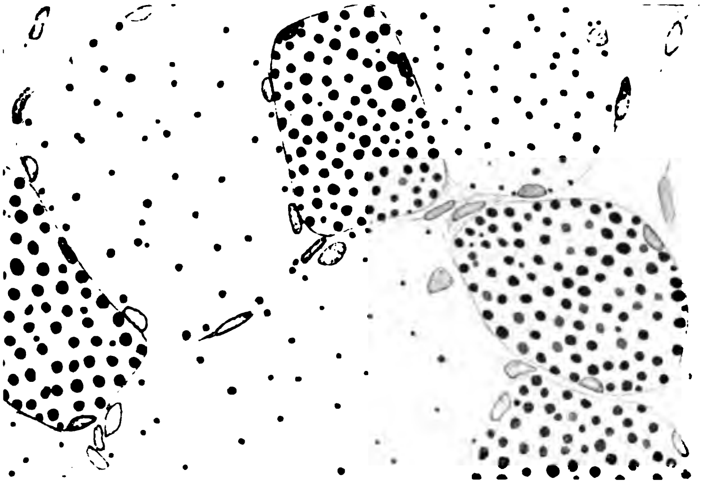
Knoll ('89) concluded that the dark appearance of muscle fibers is due to the presence of interstitial granules, the dark fibers, he states, have many granules while light fibers are free from granules or contain only a small number. Knoll ('91) described the dark fibers as rich in interfibrillar substance or sarcoplasm ('protoplasmareich') and as containing many interstitial granules, while the light fibers were poor in interfibrillar substance (protoplasmaarm') and contained few granules. As a rule, red muscles contained more dark fibers while white muscles consisted of light fibers to a large extent. The dark fibers were usually of a smaller diameter than light fibers. Knoll also held that in general the active muscles contain a larger proportion of dark muscle fibers with a corresponding increase in the number and size of the interstitial granules. Schaeffer ('93) confirmed the work of Grützner and Knoll. He also found that dark fibers showing fixed contraction nodes simulate light fibers. Bell ('11) found that, in general, dark fibers contained coarse, strongly-refractive 'liposomes,' while light fibers contained small faintly-refractive liposomes. He stained the liposomes (fat droplets) with Herxheimer's solution of Scharlach R and in this way demonstrated the types of fibers.

The reader is referred to the papers of Knoll, Schaeffer, and Bell for an account of the general occurrence and distribution of light and dark fibers in different animals. The work of these authors has shown that differences in opacity, corrresponding to light, dark, and intermediate fibers, occur in the striated muscles of many animals, including practically all those most commonly employed in the laboratory.

In my studies the light and dark fibers were easily observed in transverse sections of fresh tissue cut on the freezing microtome. The difference in opacity is most marked when the specimen is mounted in normal saline and examined with low magnification, the reflected light being cut off by a paper shield or by some other means. The types of fibers were also demonstrated by staining frozen sections with Herxheimer's Scharlach R, with Nile blue, or with Cresylviolett. In the pectoral muscles of the pigeon where the true interstitial granules are large and numerous, the types of fibers were distinguished by the Weigert and Altmann methods as well as by the other methods just mentioned.

The light, dark and intermediate types of muscle fibers are clearly marked in unstained frozen sections of fresh material from normal cats, dogs and rats. If such sections be placed in absolute alcohol for a few minutes and subsequently examined under the microscope the dark and intermediate fibers assume the appearance of light fibers. The fat droplets and also the alcohol-soluble portion of the true interstitial granules have been removed by the alcohol, and the removal of these droplets and granules causes the dark fibers to lose their opacity. In the dog, cat and rat the true intersitial granules are small and the opacity of the dark fibers is largely due to fat droplets. In the pectoral muscles of the pigeon and the bat, not only fat droplets but also true interstitial granules are an important factor in causing the dark appearance of fibers. Sections of formalin fixed material from the pectoral muscles of the pigeon after treatment with absolute alcohol ten to twelve hours still show the dark fibers much more opaque than the light, while in similar preparations from the dog, cat or rat, dark fibers have lost their opacity and have the appearance of light fibers. The fat droplets have been removed by the alcohol but the large true interstitial granules of the pectoral muscles of the pigeon remain and cause the opaque appearance of the dark fibers to be retained. The staining reactions and solubility of fat droplets and true interstitial granules will be dealt with later, but I may here mention that formalin coagulates the true interstitial granules in such a manner as to partially protect them from the action of fat solvents while fat droplets are readily soluble both before and after formalin fixation.

Figure 1 represents the types of fibers in the pectoralis major of an exceptionally well nourished white rat. The preparation was stained by Herxheimer's method. Figure 2 shows a similar specimen from a very emaciated rat. The dark fibers so apparent in the well nourished animal have largely disappeared in the poorly nourished animal. The granules shown in the figures are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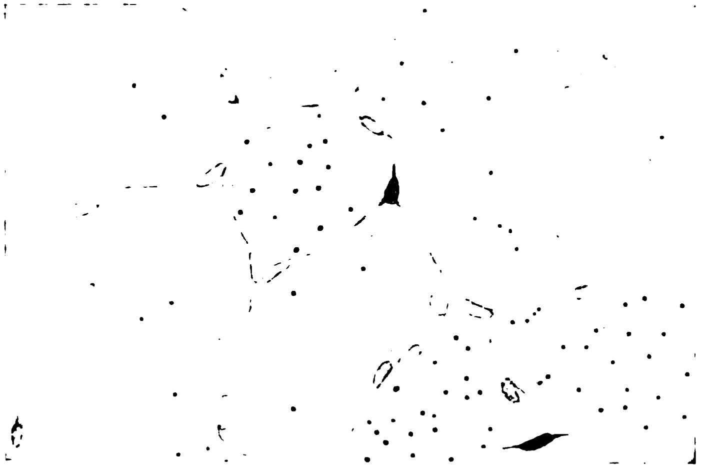
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Fig. 1 Transverse section of muscle fibers from the pectoralis major of a rat which had been fed on fat meat. Fat droplets (black) are stained red by Herxheimer's Scharlach R. The larger fibers are 'light fibers', the 'dark fibers' are smaller. × 600.

Fig. 2 Transverse section of muscle fibers from the pectoralis major of an emaciated rat. Fat droplets (black) are stained red by Herxheimer's Scharlach R. Both 'light and 'dark' fibers are shown. × 600.

fat droplets. Bell ('11) first clearly demonstrated that the fat content of muscle is largely dependent upon the nutritive condition of the animal. This subject will be referred to later.

The relative number of light, dark and intermediate fibers is known to be exceedingly variable. For any given muscle of a given species the percentage of each type is fairly constant under normal nutritive conditions, although individual variation occurs. Dark fibers have more interfibrillar substance or sarcoplasm and are commonly of lesser diameter than light fibers. However, the dark fibers in eye muscles (human) are as large or even larger than the light fibers. In the pectoralis major of the pigeon light fibers are exceptionally large with nuclei placed in the substance of the fiber, while dark fibers are small and the nuclei are peripherally situated. Mammalian skeletal muscle, in so far as I have observed, has peripherally situated nuclei in both types of fibers. The pectoral muscles of the bat are peculiar in that the fibers are all small and correspond to dark fibers as found in the pigeon. The fat content of the dark fibers of the bat as shown by Herxheimer's Scharlach R varies somewhat in the different fibers and this may be considered as an indication of the two types.

The two types of fibers, dark and light, are clearly marked in the human fetus of seven months and of eight months. I have also found the two types in the ox fetus from 45 to 65 cm. and at full term. In so far as I know dark fibers in the fetus have not been previously described.

b. Relation of light and dark muscle fibers to white and red muscle

Red muscles, as the pectoralis major of the pigeon and bat, commonly show a high percentage of dark fibers, while the white muscles of the rabbit and certain other animals may be made up largely or wholly of light fibers. By many text books and by even a recent author, Ewald ('10), the terms red and white muscle fibers are used synonymously with dark and light fibers. Such a terminology is probably founded upon a misconception and should be discontinued. The white muscles of the frog during the winter season show under the microscope a large percentage of very dark fibers and frequently red muscles, as cardiac muscle in certain individuals, show only light fibers. It is clear that dark fibers do not necessarily give a red color to muscle nor does the presence of light fibers in red muscle make it less red in appearance.

According to Krause ('11) red and white muscles in the rabbit differ only in number and arrangement of blood vessels and in amount of connective tissue. I am unable to say to what extent the red color of muscle is due to the presence of blood. Lelièvre and Retterer ('09) studied the structural differences between the red and white muscles of the rabbit. They concluded, among other things, that the membrane of Krause (*Z*, Strie d'Amici) is absent from white muscle (adductor magnus). I have examined the fibers of the adductor magnus of the rabbit and find the membrane of Krause present and clearly visible in both fresh and fixed preparations.

c. *Morphology and position of fat droplets*

Krause ('73) observed a regular arrangement of the interstitial granules in transverse rows situated in segment *J* on either side of Krause's membrane, *Z*. The observations of Krause have been confirmed by Retzius ('90), Arnold ('00), Holmgren ('07,–'10), and many others, and it has also been observed that the position of the granules as described by Krause applies to that of both the true interstitial granules and fat droplets. Retzius, Holmgren and others have described large interstitial granules as occurring in the anisotropic segment *Q*, (Brücke's disc).

The fat droplets of muscle fibers are in general spherical. Their form may be modified by the pressure of the muscle columns. Droplets that have a diameter exceeding one micron frequently show a certain amount of elongation in the direction of the longitudinal axis of the fiber. Exceptionally, the longitudinal diameter of elongated droplets is nearly twice the transverse diameter. Upon contraction of the fiber, droplets become more spherical or even flattened in the transverse direction. Occasionally, and especially in human muscle, the fat has a granular form, the evenly rounded contour of droplets being absent. Possibly this is due to post mortem changes. I am not here referring to the pigment granules of irregular form so frequently present in human muscle, especially in cardiac muscle.

Fat droplets occur in varying sizes. Apparently the smallest droplets are beyond the limit of microscopic vision. Bell ('11), staining muscle fibers by Herxheimer's method, shows 'liposomes' (his fig. 4, plate 16) which measure less than 0.5 mm. after a magnification of 1300. This means that they have a diameter of less than 0.5 μ. According to Heidenhain ('00), 0.2 μ is the extreme lower limit of microscopical vision (n. a. l. 4), and if perchance any structure of smaller size were visible it would still appear to have a diameter of 0.2 micron. Herxheimer's Scharlach R, as well as Nile blue frequently forms precipitates in the tissues but precipitate granules lack the refractive character of fat droplets and when of appreciable size the two are easily distinguishable. Precipitate in a finely granular form may be confused with minute fat droplets, and for this reason I have preferred to regard as probably a precipitate, all granules having an approximate diameter of 0.5 μ or less. The diameter of the fat droplets, which differs with the nutritive condition and with the species of the animal, seldom, if ever, exceeds 3 μ in normal mammalian muscle. Fresh preparations stained in Herxheimer's Scharlach R often show droplets as large as 5 to 6 μ, but the examination of fresh material to which no foreign fluids have had access has convinced me that such large globules arise by the confluence of smaller droplets.

The fat droplets seldom show a regular arrangement within muscle fibers in preparations made from fresh material without fixation. To demonstrate the position of fat droplets, portions of muscle were stretched upon card board or small pieces of glass and while still warm placed in 20 per cent formalin in a 0.75 per cent solution of sodium chloride. After fixation of two to twenty-four hours, sections were cut on the freezing microtome and stained by Herxheimer's method or by the Nile blue method.

Figure 3 shows the droplets in a portion of a longitudinal section of a dark muscle fiber from the pectoralis major of an adult cat. The droplets are in transverse rows in segment *J* on either side of the membrane of Krause, *Z*. An arrangement in longitudinal rows is also apparent. Figure 4 represents a portion of a light fiber from the same specimen. The droplets are fewer in number and somewhat smaller than in the dark fibers. The arrangement is similar in the two types. Droplets may be smaller than those shown in the figures and placed nearer to the membrane Z, thus making it difficult to see two distinct rows. Droplets in dark fibers which show a large quantity of fat, may all be of small size, not exceeding 1 μ and arranged as in figure 3. Dark fibers may show longitudinal rows of small droplets placed at frequent intervals between less frequent rows of larger, elongated droplets.

In transverse sections the droplets are situated between the muscle columns or Cohnheim's areas. The larger droplets are at nodal points in the sarcoplasmic net work. No droplets are found between the individual myofibrils within the muscle columns. In muscle fibers of a type which have large true interstitial granules (granules of segment Q, pectoral muscles of the pigeon and bat and in cardiac muscle), the fat droplets when small are placed in segment J, while larger droplets extend into segment Q. In this type of muscle the droplets in segment J may be placed on either side of the membrane of Krause, Z, but frequently droplets are in a single row occupying the position of the membrane. Fat droplets are also of almost constant occurrence in the sarcoplasm beneath the sarcolemma and surrounding the muscle fiber nuclei of skeletal muscle, and they are equally constant in the central perinuclear sarcoplasmic accumulations of cardiac muscle.

d. Morphology and position of true interstitial granules

Figure 5 represents the true granules in one of the dark muscle fibers of the pectoralis major of the pigeon, longitudinal section, Weigert method. The granules are rod shaped, being approximately 1 μ in diameter and 2 μ in length. In position they correspond to segment Q and represent Holmgren's Q granules. Figure 6 represents a portion of a similar fiber, from the same muscle, stained with Nile blue sulphate after formalin fixation. By this method true interstitial granules are stained blue while fat droplets are colored red. The fat droplets, for the most part, are situated in segment J at the poles of the true interstitial granules. Occasionally the substance of the *Q* granules appears to partially surround a fat droplet. In formalin-bichromate material with the Weigert and Altmann methods, vacuoles left by the extraction of fat droplets during the paraffin process, are sometimes seen within the substance of the granule but usually the vacuoles are in segment *J* at the poles of the granules as shown in figure 5. The vacuoles thus correspond in position to the polar fat granules which Holmgren describes as of occasional occurrence.

Transverse sections show the true interstitial granules between the muscle columns. When demonstrated by the formalin-bichromate Weigert or Altmann methods, they appear rounded; or flattened in transverse section. In frozen sections stained with Cresylviolett or Nile blue sulphate, the granules are seen as stellate bodies which may occupy almost the entire space between the muscle columns (fig. 7). In describing this appearance in unstained preparations, Kölliker ('88) speaks of granules provided with wing shaped processes.

When frozen sections of formalin fixed material are treated with absolute alcohol and subsequently stained, Cresylviolett stains the true interstitial granules (pectoral muscles of the pigeon) rather faintly but the processes which give the stellate or irregular

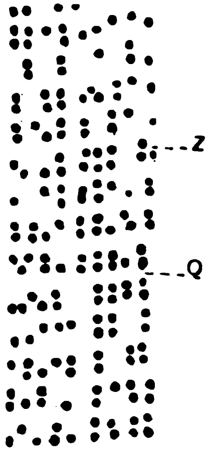
Fig. 3 Portion of a longitudinal section of a dark muscle fiber from the normal pectoralis major of an adult cat. Fat droplets (black) are stained red by Herxheimer's Scharlach R. Membrane of Krause is situated at *Z*; *Q*, position of anisotropic disc. × 1500.

Fig. 4 Portion of a longitudinal section of a light muscle fiber from the normal pectoralis major of an adult cat, stained as in figure 3; *Z*, position of Krause's membrane; *Q*, position of anisotropic disc. × 1500.

Fig. 5 Portion of a longitudinal section of a dark muscle fiber from the normal pectoralis major of a pigeon. True interstitial granules, *g*, (black) are stained blue by a modified Weigert process. Fat droplets appear as vacuoles, *a*. The letter *m* indicates muscle columns; *z*, Krause's membrane. × 1500.

Fig. 6 Portion of a dark muscle fiber from the normal pectoralis major of a pigeon, stained by Nile blue. Fat droplets, *a*, are stained red (black); true interstitial granules, *g*, are stained blue (gray); *m*, muscle columns; *z*, Krauses' membrane. × 1500.

Fig. 7 Transverse section of a dark fiber and a portion of a light fiber from the normal pectoralis major of a white rat, stained with Cresylviolett. Fat droplets, *a*, are colorless or a faint red, true interstitial granules, *g*, are stained blue (black). The letter *m* indicates muscle columns. × 1500.



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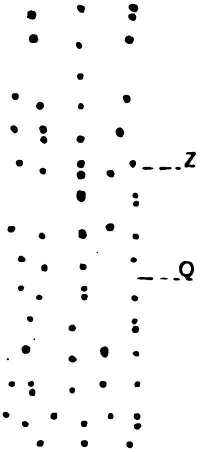

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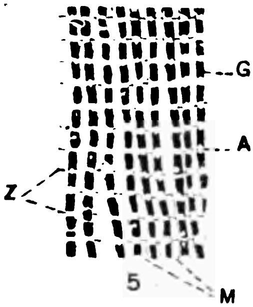

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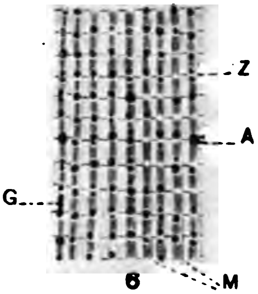

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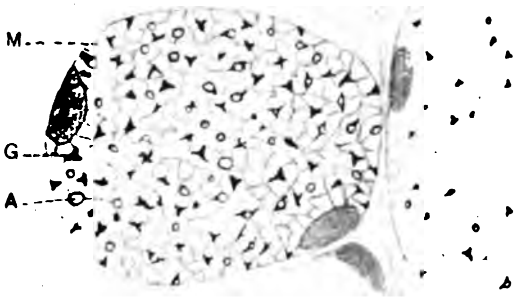

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appearance in transverse section are evidently not present. Nile blue still stains the granules with intensity but no stellate forms are visible. In this process, the fat droplets have been removed by the alcohol and also much of the substance which stains with Cresylviolett has apparently been extracted from the fiber or rendered incolorable. In formalin-bichromate material stained as either Weigert or Altmann preparations, paraffin sections, the granules seldom present the stellate form. The wing shaped processes of Kölliker may be dissolved during the process of paraffin embedding. Holmgren, however, has sometimes demonstrated the wing shaped processes by Benda's mitochondrial method.

The true granules were described above as having a rod shaped form in the breast muscle of the pigeon. This is not to be taken as invariably true. I have also observed in the pigeon muscle, dumb-bell and diplosomic forms in longitudinally cut fibers. At other times the shape is irregular and the granule is not wholly confined to the anisotropic segment. The longitudinal rows of granules in the light fibers of the pectoralis major of the pigeon are placed at greater intervals than in dark fibers though the granules are somewhat smaller in the former.

The true granules of the pectoral muscles of the bat are similar in number, size, and position to those of the pigeon. However, in the skeletal muscle of most mammals (dog, cat, rabbit) the granules are of smaller size and fewer in number. In logitudinal sections they may be dumb-bell shaped, rodules, or slender thread structures, either confined to segment *Q* or extending through the entire distance between adjacent membranes of Krause, *Z*. They may occur as spherical bodies having a diameter of 1 μ or less and situated in segment *J* on either side of Krause's membrane. The appearance is then similar to that shown for fat droplets in figure 3. The occurrence of true granules in segment *J* is described by Holmgren ('10) as typical for mammalian skeletal muscle. The stellate or irregular forms in transverse sections shown by staining with Cresylviolett were of constant occurrence in all the animals used in this investigation. They may be demonstrated in both light and dark fibers, even when granules appear to be absent by the Weigert and Altmann methods.

In cardiac muscle (pigeon, dog, rat) the true interstitial granules are present in very striking numbers. They are usually confined to the segment *Q* and correspond to Holmgren's *Q* granules. Regaud ('09) described and figured the granules in the cardiac muscle of the dog as plate-like structures, confined to segment *Q* and extending radially between the muscle columns from the periphery of the fiber toward the central sarcoplasmic column. I have examined the cardiac muscle of several dogs and find the true interstitial granules as described by Regaud.

In the wing muscle fibers of insects the granules are very similar in form and position to either the granules of the pectoral muscle the pigeon and the bat or to those of cardiac muscle in vertebrates. The wing muscle fibers of the Belostoma Americana show rounded granules in transverse section similar to those of the pigeon. The fibers of dragon flies have granules of a plate-like form similar to those of the cardiac muscle of the dog. I have not examined fibers from the leg muscles of insects.

Retzius ('09) believed that the interstitial granules are united and held in position by a fibrous network, which he demonstrated with gold chloride. A comparison of gold chloride preparations with others made by the various methods already mentioned, leads me to believe that the appearance of a net work uniting the interstitial granules is to be interpreted as a precipitate of gold.

The position assumed by the granules appears to be determined solely by their size and the pressure of the muscle columns. Perhaps also the position of both the true interstitial granules and fat droplets may be taken as affording evidence in support of the now commonly accepted view that the membranes of Krause are present in the sarcoplasm between the muscle columns. The dumb-bell and diplosomic granules may be formed by a thickening of the muscle columns at Hensen's line. After fixation, and due to the process required for embedding, the substance of the column shrinks leaving its impress upon the granules. The plate-like forms occur in types of muscle that present a radial arrangement of the muscle columns. The substance of the granule occupies the space between the columns and thus, in transverse sections, appears in the form of a plate.

In general it may be said that the shape of the true interstitial granules indicates that in fresh, unfixed muscle they are composed of a plastic, yielding substance which easily takes the form imposed by surrounding structures of a more resistant nature. Probably the term granule is a misnomer, but it is here used because it has become firmly fixed in the literature.

Kölliker ('88), Holmgren ('07, '10), Thulin ('09) and Knoche ('09) believed that the true interstitial granules possess a limiting membrane. In Weigert, Altmann, Cresylviolett and Nile blue preparations, I have observed nothing which can be taken as indicating the existence of such a membrane. The membrane-like appearance in fresh unstained preparations is, in all probability, an optical effect due to differences in refractive index.

IV. GENERAL OCCURRENCE OF INTERSTITIAL GRANULES AND FAT DROPLETS

General occurrence of true interstitial granules

Kölliker ('89) described the true interstitial granules as of constant occurrence, sometimes in enormous numbers, in the striated muscle fibers of all classes of vertebrates and insects. Knoll ('91) observed the true interstitial granules in a large number of animals including amphibians, reptiles, birds and mammals. Retzius ('09) described his sarcosomes (true interstitial granules) in insects and mammals. Altmann ('94) demonstrated the granules in insects and in the frog. Holmgren ('07–'10) described Kölliker's granules as occurring in insects and in vertebrates, rabbit, guinea pig, rat and white mouse.

The large true interstitial granules are included in nearly every description of insect muscle. Similar granules in vertebrate muscle, although described by the investigators just mentioned and by many others, have frequently been overlooked. This applies not only to text books but likewise to recent original articles.

The white muscles of the rabbit show, by the Weigert or Altmann method, only a few granules or none at all and the red muscles may show but a limited number. In the dark fibers of the dog and the gray rat, granules are larger and somewhat more numerous than in the rabbit, especially in the muscles of the tongue and in the diaphragm. In the powerful and active pectoralis major of the pigeon and of the bat, the true interstitial granules as demonstrated by the Weigert method are relatively large and occur in great numbers in each fiber (fig. 5). In so far as I have observed, the granules which stain blue with Cresyl-violett, (fig. 7), may be demonstrated in considerable numbers in every striated muscle fiber of all vertebrates. As already mentioned, granules to be demonstrated by this method do not always correspond with those shown by the Weigert and Altmann methods.

In cardiac muscle, as pointed out by Kölliker, Knoll and Holmgren, the granules are especially abundant. I have examined the heart muscle of the dog, the rat and the pigeon. The number and size of the granules is very striking. I have not been able to demonstrate the true interstitial granules in human cardiac or skeletal muscle, due doubtless to the fact that fresh material was not obtainable.

General occurrence of fat droplets

Kölliker ('88, '89) describes fat droplets as of general occurrence in muscle fibers of insects and vertebrates. However, he was evidently somewhat in doubt as to their being true fat droplets. He speaks of the droplets as fat like granules or as the long known dark (fat?) granules. Walbaum ('99) examined the muscles of 119 human bodies. He found fat droplets in some of the fibers of about two-thirds of the cases examined. Droplets were most numerous in the eye muscles and of very infrequent occurrence in the diaphragm. Ten per cent formalin was used as a fixative. He examined teased preparations in water and in normal saline and observed that many of the fatty droplets are left unstained by Sudan III. Retzius ('91) believed that fat droplets are not normally present in muscle fibers. Among others Stadkewitch ('94), Ricker and Ellenbeck ('99) and Kemp and Hall ('07), may be mentioned as failing to find fat droplets in the normal muscle fibers of adult vartebrates. As is well known, the muscle fibers of the winter frog are crowded with fat droplets while such droplets are usually supposed to be absent in summer frogs caught in the field.

Fat droplets have often been overlooked in skeletal muscle due to the fact that they are so frequently lost in the fixatives employed (formalin) and may often be left unstained by osmic acid and Sudan III. Bell ('11) who employed Herxheimer's Scharlach R on fresh tissue has demonstrated that 'liposomes' occur under normal conditions in all vertebrate muscle. He states that the number and size of the liposomes vary in different species and individuals and also with nutritive condition. He examined no human muscle.

The dog, cat (figs. 2 and 3) and rat (figs. 1 and 2) may be mentioned as examples of animals commonly having a large quantity of fat in their skeletal muscle fibers while the fibers of the ox and the rabbit have considerably less. I think that an extensive investigation might show that fibers of herbivorous animals do not store fat to such a great extent as is the case in carnivora.

Human skeletal muscle. I have examined some of the muscles, usually diaphragm, pectoral and eye muscles from about twenty-five autopsies and conclude that fat droplets occur constantly and abundantly in normal human muscle. Fat in the diaphragm was present in large amount in about half the cases examined. In two or three cases the droplets in the fibers of this muscle were few in number or possibly absent but I think that this may be attributed to pathological conditions, poor nutrition or to post mortem change. I have never failed to find fat in human eye muscle, usually in large amount.

Cardiac muscle. I have examined sections from the right ventricle of the hearts of about twenty-five dogs and cats, a dozen rats and several mice. Fat in varying amounts was found within the muscle fibers of all these animals. In two dogs only a few small droplets were to be seen, but usually in this animal fat was present in moderate amount. An exceptionally large amount of fat was present in the cardiac muscle fibers of a well nourished rat and of a pregnant cat.

Human cardiac muscle. Of fifteen hearts, fat droplets were present in ten. Two or three of the remaining five were examined after most decided post mortem changes had taken place. Fat droplets in the human cardiac fibers are commonly regarded as occurring only under pathological conditions. I believe that a thorough investigation of the subject, with the aid of the best technique would demonstrate that fat droplets of small size are of normal occurrence in human cardiac muscle fibers.

Fetal muscle. Kainath ('04) examined the skeletal muscles of the ox fetus. He found fine fat droplets in the fibers from the 3.5 to the 12.5 cm. stage but none were present in the fetus of 20 cm. and 40 cm. Bell ('09) found fat in the muscle fibers of the ox fetus from the 7 to the 28 cm. stage, but observed none in the fibers of seven fetuses of later stages.

The muscle fibers of the early fetus were not examined in this study but I have found a large amount of fat in the fibers of the ox fetus from the 35 cm. stage to full term. The dark fibers contain many fat droplets while light fibers have but a small number. I have also examined the skeletal muscles of a seven months and eight months human fetus. The dark fibers were crowded with fat droplets.

V. CHEMICAL NATURE OF INTERSTITIAL GRANULES AND FAT DROPLETS

A qualitative chemical analysis, in vitro, of the true interstitial granules and fat droplets of muscle fibers is beset with obvious difficulties and such an investigation has never been attempted. One can, however, draw certain conclusions respecting the chemistry of these bodies by a consideration of the nature of the various methods used in demonstrating them in tissue sections.

a. Chemical nature of true interstitial granules

Kölliker ('57) states that the true interstitial granules, being very pale, especially in mammalian muscle, have been overlooked by previous observers. He finds the granules insoluble in alcohol and ether. Kölliker ('88) concludes that, chemically, the granules are identical with no known substance. They contain no glycogen for they do not give the iodine reaction. Retzius ('90) considers the true interstitial granules to be of a non-fatty nature. He terms them 'sarcosomes' in order to distinguish them from pathological fat droplets. Knoll ('80, '81, '91) believes the true interstitial granules of Kölliker to have a fatty marginal layer and a central portion possibly of lecithin. Arnold ('07) thinks that the glycogen of striated muscle is bound to the sarcosomes. He observed that sarcosomes which contain glycogen stain by Best's carmine method ('06) while those that are free from glycogen remain colorless. Regaud and Favre ('09) demonstrated granules in the tongue muscles of the rabbit by Regaud's formalin-bichromate iron-hematoxylin method. They believed these granules to correspond to Kölliker's granules. Chemically they were thought to be an albumino-lipoid. Bell('11) finds that the large *Q* granules of insects contain no fatty substance and are widely different chemically from the interstitial granules of vertebrate muscle. He thinks that the microsomes of Altmann may be artefacts, and is evidently of the opinion that other observers have mistaken fat droplets in vertebrate muscle for the true interstitial granules.

1. Refractive character. Fibers from the pectoralis major of the pigeon or the wing muscles of an insect may be teased and placed, without the addition of fluid, upon a slide, the cover glass being applied with slight pressure. Such preparations show the fat droplets as highly-refractive globules but the true interstitial granules seem to have approximately the same refractive index as the substance of the muscle columns and are not clearly visible. However they may be seen as faintly-refractive bodies after normal saline has been drawn under the cover-glass.

2. Solubility. As has been observed by Kölliker and others the true interstitial granules are disintegrated and partially dissolved by water. In order to test the effect of fat solvents upon the granules I have examined sections prepared by the paraffin process after fixation in 97 per cent alcohol. In sections from the heart or pectoral muscles of the pigeon, the granules in alcohol fixed material are seen as broken fragments. A comparison of these sections with others made after formalin-bichromate fixation shows that a large part of the substance of the granules has disappeared from the alcohol fixed material. This suggests the idea that the partial disappearance of the granules from alcohol fixed material may be due to the solution of a fatty substance which can be rendered insoluble by the action of potassium bichromate. It was found, however, that the granules of material fixed in 20 per cent formalin show no more shrinking after the paraffin process than do those of formalin fixed material which has been mordanted in potassium bichromate before the alcohol and xylol preceding embedding. Thin paraffin sections were also washed in several changes of hot ether four to six hours and subsequently examined under the microscope after staining with acid fuchsin or hematoxylin. The fat extraction by this method is considered more complete than by the Soxhlet's apparatus as ordinarily employed. Ether does not dissolve the true interstitial granules from paraffin sections of formalin fixed material taken from the pectoral muscles of the pigeon. The partial disappearance of the granules, from alcohol fixed material, takes place in the alcohol and xylol, and the subsequent treatment with ether appears to have little effect. If we suppose that the shrinkage or disappearance of the granules in alcohol or xylol is due to the extraction of a fatty substance, it is also necessary to suppose that the fatty substance is in part rendered insoluble in alcohol, xylol and ether by the coagulative action of the formalin on the non-fatty substance of the granules. As will be seen below, however, staining with Cresylviolett indicates that the true interstitial granules are soluble in alcohol to a very considerable extent even in formalin fixed material

3. Results with Cresylviolett R R, Cresylechtviolett, and Nile blue sulphate. Krause ('11) recommends Cresylviolett R B in dilute aqueous solution for demonstrating the interstitial granules in fresh tissue. I have used Cresylechtviolett and Cresylviolett R R which are apparently similar to the dye employed by Krause. The fat droplets are not stained to any considerable extent by Cresylviolett. Occasionally they show an exceedingly faint red color or a more intense peripheral blue staining but usually they are left colorless.

As mentioned above, the true interstitial granules are partially dissolved by water. Since this is the case, one should not expect to obtain a true picture of the granules by the use of an aqueous staining solution on unfixed material. The arrangement of the granules is often very irregular in Cresylviolett preparations of unfixed material especially if the section is exposed to the action of water previous to staining or left too long in the stain, or if the material is taken from animals following rigor mortis. Under such circumstances granules are absent from portions of the fiber and are aggregated in masses within other portions of the fiber or beneath the sarcolemma. The blue stained substance, however, is not easily, if at all, soluble in water. Aqueous solutions of Cresylviolett may also be applied to frozen sections of material fixed fresh for two to twenty-four hours in 20 per cent formalin in a 0.75 per cent sodium chloride solution. Such preparations show a comparatively uniform arrangement of the blue staining granules corresponding to that of the true interstitial granules of Kölliker.

It has already been mentioned that the wing shaped processes of Kölliker, which give the granules a stellate appearance, are not stained by Cresylviolett when the section has been previously treated with alcohol. In formalin fixed material the large granules of the pectoral muscles of the pigeon can be stained intensely with Nile blue or faintly with Cresylviolett even after the action of alcohol. The true intersititial granules in the muscle fibers of the dog, cat, rat and rabbit stain with Cresylviolett and for the most part appear to be soluble in alcohol both in fresh material and in formalin fixed material for they cannot be stained when sections have been previously treated with absolute alcohol. When this material has been kept in 20 per cent formalin for several weeks, the wing-shaped processes and soluble granules seem to have disappeared and can no longer be demonstrated by Cresylviolett or Nile blue sulphate. Even after prolonged exposure to formalin the true interstitial granules in the pectoral muscles of the pigeon are still readily stained by Nile blue sulphate and faintly colored by Cresylviolett.

If it be supposed that the alcohol-soluble substance of the true interstitial granules is a form of fat, the fact that it stains with basic dyes may indicate that it is a lipoid or fatty acid.

4. Results with the methods of Weigert, Altmann, Benda and Regaud. To demonstrate the true interstitial granules, Altmann ('94) employed his bichromate-osmic acid-fuchsin method. Holmgren ('10) made use of Bend's mitochondrial method and Regaud ('09) used his formalin-bichromate iron-hematoxylin method. I find that the granules may be demonstrated in a satisfactory manner by any of the above methods as well as by the Weigert method which involves formalin-bichromate fixation followed by hematoxylin staining. Similar results by these methods is to be expected for the methods are chemically similar although the stains employed, acid fuchsin, Crystallviolett, hematoxylin, and iron-hematoxylin, are of a varied character.

Smith, Mair and Thorp ('08) have explained the chemistry of the Weigert hematoxylin process. They found that the method depends upon the oxidizing action of potassium bichromate upon unsaturated fats. The oxide of chromium forms with the fat molecules a compound which is insoluble in fat solvents and capable of forming a lake with hematoxylin. It is only during the process of oxidation that the fat-chrome compound forms the hematoxylin lake. After complete oxidation the staining no longer takes place. These observers found the method applicable not only to unsaturated fats, as oleic acid and triolein, but also to lipoids in which unsaturated groupings occur such as cholesterin and cerebrosides. The work of Smith, Mair, and Thorp was confirmed and extended by Fauré-Fremiet, Mayer, and Schaeffer ('10). They found that not only the unsaturated but also certain of the saturated fatty acids, including palmitic, are rendered insoluble in alcohol and xylol by oxidizing reagents and also by the action of salts of the heavy metals. (Benda explained the action of the salts of copper on fatty acids as depending upon the formation of insoluble copper soaps.) These insolubilized fats were stained with more or less intensity by both acid and basic anilin dyes and in certain cases (after copper or chromic compounds, salts of iron and of zinc) a hematoxylin lake was formed. The phosphatid lipoids were not rendered insoluble in xylol by the action of salts of the heavy metals, but were insoluble after chromic and certain other oxidizing compounds. Lipoids rendered insoluble by chromic compounds stained with considerable intensity by Orange G but could be stained with the anilin dyes only when the potassium bichromate had been kept warm during the process of oxidation. The hematoxylin lake in the case of the lipoids, did not follow excepting after a mordant such as iron alum. It was also observed that both albumino-lipoids (lecithalbumin) and mixtures of fatty acid and albuminoids were precipitated by formalin in such a way as to render the fatty substances practically insoluble in ordinary fat solvents. For example, oleic acid in a precipitated albuminous mixture was stained by various methods, even after the action of alcohol and alcohol-ether for several days at a temperature of 35°C. The methods of Altmann, Benda and Weigert, although variously modified are, according to these observers, based on the same chemical principles and give almost identical results when applied to the mitochondria (Altmann's granules or the true interstitial granules of this paper). After an extended inquiry into the chemistry of the mitochondria, they conclude that the granules contain a fatty body which is neither a neutral fat nor a soap but is probably an unsaturated fatty acid, absorbed by an albuminous granule or present in an albumino-lipoid compound.

If we assume with the authors just quoted and with Regaud and Favre ('09) that the true interstitial granules are an albumino-lipoid or a fatty-acid albuminous mixture, the action of formalin in partially protecting them against fat solvents is explained in that the albuminous component is coagulated by the formalin and the fatty component is thus rendered less easily extractable. The same assumption also permits us to explain the action upon the granules of the methods of Altmann, Benda, Weigert and Regaud. It would, of course, be a mistake to consider these methods as specific for albumino-lipoids. They are of wide application and do not afford distinctive evidence as to the chemical nature of the substances stained.

5. Results with acid fuchsin. Knoche ('09) obtained a microchemical xanthoproteic reaction with the true interstitial granules of Kölliker and belived that the proteid thus shown was an albuminous substance. He states that the granules have a capsule which stains with acid fuchsin but he does not give the details of his technique. As has been previously mentioned, the entire granule is readily stained in formalin-bichromate material with Altmann's acid fuchsin. Employing material from the pectoral muscles of the pigeon and bat and from the wing muscles of insects, I have also found that Altmann's acid fuchsin stains the granules after simple formalin saline fixation (paraffin process) the potassium bichromate being unnecessary. The fragmented granules in alcohol-fixed material are not stained by Altmann's acid fuchsin.

Smith and Mair ('11) find that lecithin and sphingosine stain readily with acid fuchsin both before and after the action of potassium bichromate. They think the presence of either of these substances would explain the staining of Altmann's acid fuchsin granules. Pure lecithin, according to these observers, does not stain by the Weigert process, but they add that it stains readily if it has the slightest admixture of cholesterin. Fauré-Fremiet, Mayer and Schaeffer ('10) state that lecithin and other lipoids fail to stain by the Weigert process, but may be stained by hematoxylin if preceded by iron alum. Since the true interstitial granules stain readily by the Weigert process, the iron alum not being necessary, we may conclude that if the staining of these granules depends largely on lecithin, as suggested by the acid fuchsin method, the lecithin is not in a pure state.

Fatty acids, according to Smith and Mair ('11), do not stain with acid fuchsin either before or after the action of potassium bichromate. Fauré-Fremiet, Mayer and Schaeffer ('10), on the other hand, find that fatty acids are faintly stained by this dye, both before and after bichromating, presumably with greater intensity in the latter case, for they think that the presence of fatty acid would account for the staining of Altmann's granules. I have stained tissue paper smears of oleic acid (Kahlbaum) after treatment for a variable length of time (one to six days) in saturated potassium bichromate. The smears were stained with acid fuchsin either Altmann's mixture or in alcoholic solution, heating according to the method of Altmann. The droplets were stained a somewhat pale red. The color in the case of oleic acid appears to be too faint to fully account for the intense red of the true interstitial granules, and thus it is doubtful that these granules contain a pure oleic acid.

6. Results with Sudan III, osmium tetroxide, gold chloride. Sudan III does not color the true interstitial granules unless we take into account an extremely faint yellow to be obtained after the action of potassium bichromate. The granules are slightly darkened, but not blackened, by 2 per cent osmic acid followed by pyroligneous acid or by alcohol for reducing the osmium. Retzius ('90), Knoll ('91), and others have stained the true interstitial granules with gold chloride but the gold precipitate is not considered differential for the presence or absence of fat.

7. Summary. The observations presented above are of too general a character to permit of definite conclusions as to the chemical nature of the true interstitial granules of Kölliker. It is certain that the granules contain a non-fatty element, probably of a proteid nature. It may be stated that the substance upon which depends their staining by basic dyes, as well as by the more complex methods of Altmann, Weigert and Regaud, is a substance soluble in fat solvents. In part this soluble substance may be protected from fat solvents by the action of formalin as well as by chrom-osmic mixtures. The solubility and staining reactions of the granules indicates that they may be an albumino-fatty compound or mixture, possibly an albumino-lipoid. There is no reason to suppose that the granules in muscle fibers are fundamentally different chemically from granules to be demonstrated by similar methods in other tissues of the body. It is reasonable to suppose that the true interstitial granules of muscle fibers are subject to some variation chemically in different species and under varying nutritive conditions.

b. Chemical nature of fat droplets

The fat droplets of muscle fibers are mentioned by many observers but few have attempted to determine the exact chemical nature of the fat. Usually, it seems, the droplets have been looked upon as neutral fat. As already mentioned, Knoll ('80, '81, '90) thought the true interstitial granules to be composed, in part at least, of lecithin, but he too considered the fat droplets to be neutral fat. Bell ('10) holds that neutral fat droplets in muscle fibers are readily stained by simple alcoholic solutions of Scharlach R, but many 'liposomes', which are not so highly refractive as neutral fat droplets and consist wholly or in part of lipoids, can be stained only by alkaline Scharlach R (Herxheimer's method). Bell ('11) thinks the liposoms consist mainly of olein together with some low-melting fat other than olein. He states that many faintly-refractive liposomes which do not stain readily with simple alcoholic solutions of Scharlach R or with osmic acid, are stained somewhat faintly by Herxheimer's method and are composed in part of a substance other than fat, possibly an albumino-lipoid. Liposomes which stain faintly by Herxheimer's method and contain a non-fatty element are believed by Bell to be of most common occurrence in the muscle fibers of poorly nourished individuals.

1. Refractive character: Double refraction. The fatty droplets of muscle fibers may be seen in fresh tissue to which no foreign substance has had access. Preparations are made by rapidly teasing the fibers on a slightly warmed slide and applying a cover glass with slight pressure. The droplets present the highly refractive appearance characterisitic of fat droplets and must be regarded as pre-existing bodies, that is to say they are not produced by histological reagents. Fat droplets are well brought out in fresh preparations mounted in normal saline. They vary somewhat in refractive index in different individuals but usually the variation in a single preparation is not pronounced. The true interstitial granules may also be observed in such preparations. These granules likewise vary somewhat in refractive index but are usually less refractive than the fat droplets. Judging merely from refractive index certain granules may be classed as either faintly refractive fat droplets or highly-refractive true interstitial granules. Preparations mounted in 2 to 5 per cent potassium hydroxide show the fat droplets very clearly for an hour or more but the true granules disappear almost immediately.

Bell ('11) states that the fat droplets of muscle fibers are all isotropic. I have examined only a few specimens with the micropolariscope. The droplets were always singly and not doubly refractive. This shows that the droplets are not a fat which is fluid crystalline in form, such as the cholesterine compounds.

2. Solubility. The fat droplets of muscle fibers are readily soluble in cold absolute alcohol and in ether. Ninety-five per cent alcohol usually dissolves the droplets from frozen section or teased preparations in a few minutes. Tissue fixed in seventy per cent alcohol frequently shows a gradual diminution of the quantity of fat. It is well recognized that tests of solubility are of little value in determining the chemical character of fats in the tissues, especially as such fats, at least in most cases, are not in a pure state but exist as mixtures. Neutral fat has usually been considered insoluble in 70 per cent alcohol. However the fat droplets of muscle fibers, having a diameter of but 1 to 3 μ, must be regraded as in an extremely fine state of division, thus favoring prompt solution and, moreover, the quantity of solvent is very many times that of the fat dissolved. The fact that fat droplets in muscle fibers are sometimes dissolved by 70 per cent alcohol does not prove that they are not neutral fat.

3. Results with Scharlach R and Sudan III. Bell ('10) states that I had shown clearly the great superiority of alkaline alcoholic solutions of Scharlach R and mentions that my results had not yet been published. My observations concerning the staining of fat droplets in muscle fibers with alkaline alcoholic solutions of Scharlach R and Sudan III and with simple alcoholic solutions of the same dyes, were made in the Laboratory of Anatomy of the University of Missouri three years ago and are here given in a corrected form.. At that time I observed the position of fat droplets in muscle fibers, a subject already discussed in this paper.

Schlarlach R and Sudan III are usually employed as saturated solutions in 70 to 80 per cent alcohol. Such solutions frequently fail to stain the fat droplets of muscle fibers. The best results are obtained by heating the alcohol at the time of preparation of the stains or by permitting a certain amount of evaporation during the staining process. Even after an application of twenty-four hours, these stains may color only a small part of the total number of fat droplets which can be seen in fresh preparations or demonstrated with Nile blue. Herxheimer ('04) does not state specifically that his alkaline-alcoholic solution of Scharlach R will color any fat droplets which cannot be stained with simple alcoholic solutions but he quotes Erdheim ('03) as having made such a claim. In so far as I have observed, alkaline-alcoholic solutions of Scharlach R and Sudan III stain all the fat droplets of muscle fibers. Herxheimer's stain usually gives a deep red color to droplets faintly stained or left colorless by simple alcoholic solutions. As already stated, true interstitial granules are not stained by Sudan III and Scharlach R. Frozen sections or teased preparations of muscle fibers, as well as of other tissues, which, when stained by the ordinary stock solutions of Sudan III and Scharlach R in 70 per cent alcohol may appear fat free, are sometimes shown to be crowded with fat droplets when examined in the unstained condition or when stained with Herxheimer's stain, or with Nile blue followed by immersion in an alkaline medium. In some specimens of muscle the simple alcoholic solutions stain all the fat droplets which can be seen in the fresh tissue.

The fact that fat droplets in muscle fibers are frequently left unstained by the less concentrated solutions of Sudan III and Scharlach R does not seem to offer sufficient proof that such droplets are not neutral fat. Fat in adipose tissue of mammals which presumably is neutral fat, is occasionally colored so faintly by these stains that were it in finely divided droplets it would be almost colorless. I do not share the belief advanced by Bell that we must suppose the droplets to contain an admixture of albumin or other non-fatty substance. The droplets in the muscle fibers of emaciated individuals, in so far as I have observed, stain with as great intensity by Herxheimer's method as do those of well nourished individuals. The intensity with which droplets are stained both with Herxheimer's stain and with simple alcoholic solutions of Scharlach R depends as much upon the conditions under which the dye is used as upon the nature of the fat. The fact that droplets stain faintly cannot in itself be taken as sufficient proof that they contain a non-fatty element.

4. Osmium tetroxide. It is well known that osmic acid is reduced only by the unsaturated fats, the reduction depending upon the oxidation of the fat. Therefore it has been considered that fat droplets that are blackened by osmic acid consist, wholly or in part, of unsaturated fats. However, unsaturated fats present in small amounts as mixtures with saturated fats may fail to blacken with osmic. The fat droplets in muscle fibers of many animals do not reduce osmic acid. While in certain individuals the fat droplets blaken with osmic acid, in other individuals of the same species the reduction does not occur. This shows that the unsaturated fat in the droplets is variable in amount.

5. Results with the Nile blue method. Smith ('07) explained the staining of fats with the basic anilin dyes as depending upon the formation of color-soaps by the action of fatty acids and color bases. Neutral fat, as such, can not be stained by basic anilin dyes, but after hydrolysis the free fatty acid combines with the color base. This observer also found that neutral fat in the tissues is in a very unstable condition, being hydrolyzed by dilute acids and even by the carbon dioxide of the air. Thus neutral fat droplets in stained sections, after having been hydrolyzed into fatty acid and glycerine by exposure to the air were observed to take the color of the basic stain. Smith found that Nile blue sulphate initially gives a red color to both neutral fat and fatty acid. Neutral fat retains the red staining quality but subsequently fatty acids form color-soaps with the Nile blue base, the deep blue of the soap obscuring the comparatively faint red color of the fatty acid. Aschoff ('09) found that the phosphatid lipoids and cerebroside are also colored blue by Nile blue sulphate. McCrae and Klotz ('10), who used Nile blue on sections of fatty liver, state that they experienced some difficulty in interpreting their results. According to Klotz ('09) "The blue coloration obtained in staining sections with Nile blue is not to be depended upon as indicating in every instance the presence of fatty acids, as the shade of the color is influenced by external circumstances." He, however, does not specifically state by what circumstances the color is influenced.

Nile blue has been used as a means of investigating the chemical nature of fat droplets in tissue sections, but in so far as I know the method has not been applied to muscle fibers. I have followed directions given by Smith and Mair ('11) for the use of Nile blue sulphate but the results have not been very satisfactory. Apparently the fat droplets are decolorized by the 2 per cent acetic acid used as a differentiating fluid. The method which I have used with best success is given here under the heading "Material and methods." In brief it consists in setting free the color base by the addition of a small amount of alkali to the medium in which the section is mounted, or by washing in slightly alkaline water after differentiating in distilled water. Precipitates are formed if sections are not carefully washed before being placed in the alkaline solution. With a little care in making the preparations with Nile blue chlorhydrate, and apparently with the sulphate also, it is possible to stain all the fat droplets to be found in muscle fibers. That is to say, Nile blue will stain droplets that are not stained by simple alcoholic solutions of Sudan III and Scharlach R or by osmic acid. With Nile blue, as with other stains, fresh tissue should be used if all the droplets are to be stained, for they frequently disappear in fixed tissue.

As has already been said, Nile blue sulphate stains not only the fat droplets but, in formalin fixed material at least, it also stains the true interstitial granules. This is best shown by staining a section from the pectoral muscle of a pigeon or bat. The true interstitial granules are especially abundant and stain a bright blue, the shade depending upon the length of time in the stain and upon the reaction of the mounting medium. The fat droplets which may also be present in large numbers, usually stain a somewhat faint red but sometimes in various shades of purple or blue. In formalin fixed specimens of material containing large true interstitial granules, it is not difficult to distinguish the latter from fat droplets since the granules do not have the globular form of the droplets and for the most part present color differences.

The color assumed by the fat droplets when stained with Nile blue is of some importance as it may help in identifying the fats chemically. The color of the droplets depends, to a considerable extent upon the time occupied in staining and upon the alkalinity of the solution to which the stained section is exposed, as well as upon the length of time left in this second solution. The red staining takes place rapidly. The blue staining is sometimes well marked after fifteen minutes but may not appear for several hours or may not occur at all. The color is also influenced by the reaction of the mounting medium. In any alkaline medium the pale blue droplets tend to become red, while in an acid medium the red droplets tend to become blue. The entire mass of droplets may stain uniformly either red, blue, or in various shades of purple. On the other hand, a droplet colored red may include within its mass one or several clearly marked smaller droplets which stain an intense blue. Again, the periphery of a droplet may show blue staining while the center is red. After preparations have been mounted for a variable number of days, droplets which at first were red may assume an intense blue color. In other preparations the red color is retained for months. I have observed a certain amount of blue staining of the fat droplets in every species of animal from which material was taken, including man. The blue staining compound is found in muscle fibers taken from well nourished animals as well as in fibers from animals poorly nourished.

It is difficult to interpret the color reactions of Nile blue upon the fatty substances of muscle fibers. The blue color of fat droplets may possibly indicate that they are, in part, either fatty acid or a lipoid substance, while the red color indicates the presence of neutral fats. However, the blue color of the fat droplets may, as we have seen, indicate the presence of a neutral fat which is easily hydrolyzed, the fatty acid then forming a color soap. When the blue staining takes place only after sections have been mounted several days, it is, in all probability, dependent upon the gradual hydrolysis of neutral fat. With fresh tissues treated with the dye for a few minutes only, the blue staining, which is sometimes immediately apparent, may be due to similar changes in the neutral fat. It is possible that blue staining of fat droplets in fresh unfixed tissue or in tissue obtained some time after the death of the animal, may be due, in part, to the solution in the fat droplets of the blue staining substance of the true interstitial granules. It was pointed out by Smith ('07) that fat droplets in tissues may be hydrolyzed by the action of the formalin fixatives. It follows that in formalin fixed material the blue staining with Nile blue is often an expression of neutral fat which has undergone hydrolysis.

The fat droplets of the muscle fibers of many individuals of a species show no blue staining after a prolonged exposure to the stain. From this we may conclude that the droplets in these individuals contain little or no free fatty acids, phosphatid lipoids, or cerebroside. In no case, in so far as I have observed, does the staining with Nile blue afford convincing proof that any substance other than neutral fat is normally present in the fat droplets of muscle fibers during the life of the animal. Contrary indications may be due to postmortem changes.

6. Results with the methods of Benda, Fischler and Klotz for free fatty acids and soaps. According to Benda, neutral copper acetate forms, with free fatty acids, colored copper soaps which for the most part are insoluble in fat solvents. The methods of Benda, Fischler and Klotz depend upon this reaction. Fischler ('04) found that the fatty acid copper compound forms a lake with hematoxylin. He also stained soaps in the tissues by the same methods, the soluble potassium and sodium soaps being first converted into insoluble calcium soaps by the action of calcium salicylicum. Klotz ('06) suggested further modifications. Bell ('11) used the above methods on preparations from a considerable number of muscles, but in no case was able to get the color reaction for free fatty acids or soaps. He concludes that the liposomes (fat droplets) of muscle fibers do not contain either fatty acids or soaps. I have used these methods only to a limited extent and my results are in agreement with those of Bell. However a positive result with the methods of Fischler and Klotz should not be taken as certain proof of the existence of free fatty acid during life. The fixative employed in both these methods contains formalin and in the method of Klotz, acetic acid is added. It is thus possible that the staining occasionally depends upon the previous hydrolysis of neutral fat.

7. Results with the Weigert method and related methods. We have already discussed these methods and seen that they give positive results with the true interstitial granules. The fat droplets of muscle fibers are not easily rendered insoluble by the action of chromic compounds. For the most part the droplets are dissolved by the alcohol or xylol used in the paraffin process even when the tissues have been treated with 10 per cent potassium bichromate for several days at 37°C. It follows then that the fat droplets in muscle fibers are not shown by the Weigert or iron-hematoxylin methods as ordinarily employed. When chrom-osmic fixatives are used, as in the methods of Altmann and Benda, the droplets are sometimes blackened and rendered insoluble, but usually they are still soluble. When, as rarely happens, fat droplets are rendered insoluble by the bichromate-osmic mixtures, and at the same time not blackened by osmic, they may be stained by Benda's iron-alum Krystallviolett and probably also by hematoxylin or iron-hematoxylin. Since the investigations of Smith and Mair ('08, '10, '11), Aschoff ('09), and of Fauré-Fremiet, Mayer and Schaeffer ('10) have shown that the phosphatid lipoids, combinations of cholesterin and fatty acids, as well as cerebroside, are rendered insoluble by the action of potassium bichromate, we may conclude that the fat droplets of muscle fibers do not, to any very considerable extent, consist of these fats. Saturated neutral fats are not rendered insoluble by the action of potassium bichromate and triolein is acted upon only very slowly. The fat droplets of muscle fibers not being readily acted upon by potassium bichromate, react as if they were composed wholly or largely of neutral fat.

8. Formalin fixation. Bell ('10) pointed out the fact that fat droplets in muscle fibers and other tissues are frequently not preserved by formalin fixation. Droplets of ordinary neutral fat he states are not affected in their staining by formalin fixation, but many faintly-refractive fat droplets, consisting wholly or in part of lipoids, cannot be stained after formalin fixation. The faintly-refractive droplets are either removed or rendered invisible by fixation. He finds that the action of the formalin fixative in one tissue may be unappreciable for weeks and in another nearly all the liposomes may be removed in a few minutes. He states that the varying effect of the fixative is probably due to the varying chemical composition of the liposomes. Bell also found that usually the fat droplets in the muscle fibers of adult and well nourished animals are less affected by formalin than are the droplets of young and poorly nourished animals. However, many exceptions to this rule were mentioned. Bell ('11) confirms his former observations and states further that the faintly-refractive liposomes, which are removed by formalin fixation, consist in part of a substance other than fat, possibly an albumino-lipoid. He believes that the disappearance of the liposomes is probably due to autolysis.

I have repeatedly observed the gradual disappearance of fat droplets from tissue fixed in formalin. However, I am not certain that neutral fat is not affected by formalin fixation. Smith ('11) in fact has found that ordinary formalin solutions hydrolyze the fat droplets of frozen sections which are kept in the fixative. I have frequently but not invariably found that the blue staining of fat droplets with Nile blue is more marked in formalin fixed material. Free fatty acids are soluble in Herxheimer's staining solution and hence cannot be demonstrated by Herxheimer's method. The fat droplets of formalin fixed material frequently disappear, not being visible either as crystals or as droplets staining blue with Nile blue. This indicates that the final change which takes place in the fat is not be to explained on the basis of simple hydrolysis. I believe, however, that the initial change may be hydrolysis of an unstable neutral fat. The fat droplets of the muscle fibers of the ox fetus, for the most part, stain red with Nile blue but after several days the droplets in the stained section assume a blue color. This change of color indicates that the fat is in an unstable condition and can be readily hydrolyzed. The fat droplets of the fetal tissue were not permanently preserved by formalin fixation. The observations of Bell and Smith, as well as my own, are based on the use of ordinary commercial formalin. This solution contains variable quantities of formic acid and possibly acetic acid. The hydrolysis of the fat may depend upon the presence of these impurities. It is thus possible that the variable action of formalin is to be explained in part by the variable chemical composition of the fixative.

The action of formalin on the fat droplets is not what we should expect if the droplets were an albumino-lipoid as suggested by Bell. In fresh unfixed muscle fibers the droplets readily coalesce to form larger globules. In formalin fixed material the coalescence is not so apparent, for the substance immediately surrounding each droplet has been coagulated. However by the examination of carefully teased muscle fibers it is easy to convince oneself that the droplets themselves are not hardened but may still coalesce. If albumin were present to any considerable extent, the droplets would be fixed and no coalescence would take place. Fauré-Fremiet and his collaborators have shown that albumino-lipoids are coagulated by formalin in such a manner as to render the fatty substance almost insoluble in fat solvents. The fat droplets of formalin fixed muscle fibers are apparently as easily dissolved by alcohol as in fresh tissue.

9. Summary. The fat droplets of muscle fibers are not largely composed of fatty acids or soaps for they do not stain by the methods of Benda, Fischler and Klotz. They are not fatty acids for they do not stain readily with basic anilin dyes. The fat droplets do not contain cholesterin esters to a very considerable extent for they do not present the characteristic anisotropic fluid-crystalline form. The droplets are not phosphatid lipoids or cerebroside for these substances are easily rendered insoluble by potassium bichromate, whereas the fat droplets of muscle fibers are not rendered insoluble. Also phosphatid lipoids and cerebroside stain with basic dyes, giving blue with Nile blue, while the fat droplets of muscle, at least for the most part, stain red with this dye and are colored blue only after a chemical change has occurred in the fat. Fat droplets in muscle fibers are readily stained by alkaline-alcoholic solutions of Scharlach R and Sudan III but are frequently left unstained by simple alcoholic solutions of these dyes. The evidence which tends to show that the fat droplets of muscle fibers are neutral fat (glycerin esters of fatty acids) is largely of a negative character. It is improbable that they are pure neutral fat, yet it may be said that no certain proof has yet been offered that any substance other than neutral fat is present in the fat droplets of muscle fibers during the life of the animal.

VI. PHYSIOLOGICAL SIGNIFICANCE OF INTERSTITIAL GRANULES AND FAT DROPLETS

Physiological significance of true interstitial granules

Several investigators have held that true interstitial granules give origin to fat droplets either by a fatty metamorphosis or by serving as a focus about which fat is deposited. Kölliker ('88–89) belived that fat droplets in muscle fibers arise from true interstitial granules by a process of fatty metamorphosis and Schaeffer ('93) advanced similar views. Holmgren ('10) states that the deposition of fat in muscle fibers is apparently influenced by the true interstitial granules but he thinks the granules are actually transformed into fat only under exceptional or pathological conditions. Altmann ('94) held that his bioblasts (true interstitial granules) are not transformed in toto into fat but act as a focus within and around which fat is accumulated. Arnold has advocated similar views. Bell ('11) does not believe that granules which stain with acid fuchsin (Altmann's granules) give origin to fat and he is of the opinion that true interstitial granules do not occur in vertebrate muscle. His conception of the deposition of fat in muscle fibers is nevertheless essentially in accord with the theory advanced by Altmann. Bell holds, namely, that the fat of muscle fibers is deposited as 'liposomes' around a pre-existing non-fatty body, possibly an albumino-lipoid. As we have seen, Altmann's granules are probably an albumino-lipoid formation and conversely albumino-lipoids may be expected to stain with Altmann's acid fuchsin.

The reader is referred to the literature for a presentation of the arguments offered by various authors in support of the idea that true interstitial granules give origin to fat droplets or serve as foci about which fat is deposited. It may be said that, at present, the truth of such a conception is not sufficiently demonstrated to warrant us in believing that there is a genetic relationship between true interstitial granules and fat droplets.

According to Holmgren ('07, '10) the colorable substance (method of Benda) of the interstitial granules is necessary to the proper functioning of the contractile elements. During the latent period, substance from the granules was thought to pass into the muscle columns there to be used in the stage of active contraction. The examination of insect and vertebrate muscle fibers, by the various methods employed in this study, has afforded little in support of Holmgren's views concerning the physiological significance of the granules.

Knoll ('80) and Knoll and Hauer ('92) found that the true interstitial granules are not removed in inanition. Feeding experiments with a dozen white rats lead me to conclude that the alcohol-soluble portion of the true interstitial granules which stains with Cresylviolett is increased in amount when rats are heavily fed and decreased when the animals are kept on low rations. This may indicate that the alcohol-soluble substance is of metabolic importance and such an assumption would seem the reasonable one.

Before dismissing the subject of the physiological significance of true interstitial granules, it should be mentioned that Arnold ('09) believes that glycogen is bound to the sarcosomes (true interstitial granules), and Kingsbury ('12) thinks that mitochondria, in general, act as a reducing agent and in certain cases may be concerned in exercising the function of cell respiration.

Physiological significance of fat droplets

The presence of fat droplets in striated muscle fibers has been regarded by Van Gehuchten ('89) and others, as of pathological significance. Probably this is still the prevailing opinion with respect to cardiac muscle. Schaeffer ('93) believed that fat droplets in the skeletal muscle fibers of vertebrates may occur under normal conditions but are usually pathological. Walbaum ('99) found that fat droplets were of very frequent occurrence in normal human muscle fibers but thought the quantity of fat bore no direct relation to the nutritive condition of the individual. Kölliker ('88) regarded the fat droplets of insect muscle as reserve food material. Knoll and Hauer ('92) found that fat droplets in the muscle fibers of pigeons are removed by starvation but the true interstitial granules are not removed. Krause ('11) states that the fat droplets in muscle fibers are not independent of the nutritive condition of the animal. Bell ('11) found that the liposomes (fat droplets) of the striated muscle fibers of rats were entirely removed when the animal was starved until it had lost 25 per cent or more in body weight. During starvation, the liposomes gradually became faintly refractive and decreased in size, number and in staining intensity with Herxheimer's Scharlach R and with osmic acid. When the starved animal was again given food the liposomes gradually reappeared, increasing in size, number, refractive power, and staining intensity as the animal gained weight. In normal rats which were fed on fat meat for several days, the liposomes were greatly increased in number, size, and staining intensity. When summer frogs were fed heavily on olive oil or fat meat, there was a striking increase in size, number and staining intensity of the liposomes. No changes were produced in the liposomes by the feeding of grape sugar, starch, palmitic acid, sodium oleate, or lean meat. Since the liposomes stained faintly when they first appeared, Bell supposed that they then contained a relatively small percentage of fat together with some substance other than fat, possibly an albumino-lipoid. He regarded the liposomes as foci where fat is deposited and concluded that they consist of reserve food substances mainly, at least, in the form of fats.

In this connection I have examined the muscle fibers of a dozen white rats on various nutritive planes. Figure 1 represents fibers from the pectoralis major of an adult rat which had been heavily fed on fat meat for seven days. The fat droplets were stained with Herxheimer's Scharlach R. Figure 2 shows muscle fibers from the pectoralis major of a rat which had been kept for ten days on short rations of a fat free diet consisting mainly of cellulose. Fat cells were almost completely absent from the subcutaneous tissue and mesentery of this animal. Fat droplets are practically absent from the light fibers as shown in the figure, while dark fibers have a smaller quantity of fat than is normally present even in light fibers. In the diaphragm of this animal, the quantity of fat, although greatly reduced from the normal, was somewhat greater than that found in the pectoralis major.

The amount of fat in the cardiac muscle fibers of emaciated rats was less than in fibers of well nourished individuals. Animals fed on fat meat showed an increased amount of fat in the cardiac fibers but the increase was not so great as in skeletal muscle. The muscle fibers of the pectoralis major of normal rats kept on a diet of bread and lean meat show fat intermediate in amount to that represented in figures 1 and 2. In several rats the superficial fibers of the pectoralis major contained less fat than those somewhat removed from the surface. The fibers illustrated in the figures were not superficially placed. After rats have been fed on fat meat for a few days, the quantity of fat in the muscle fibers appears to have been increased to the maximum. Further feeding increases the amount of connective tissue fat but seems to have no effect upon the fat in the muscle fibers. As already mentioned, dark muscle fibers are more clearly marked in well nourished animals than in emaciated animals of the same species.

The fat droplets of muscle fibers are clearly to be regarded as reserve foodstuff. The work of Bell in this respect is so convincing as scarcely to require confirmation. I have not made observations on the effect of starch, sugar or protein diets, as has Bell.

VII. SUMMARY AND CONCLUSIONS

The interstitial granules of striated muscle may be classed as true interstitial granules and fat droplets as was done by Kölliker. Both the granules and fat droplets are factors in bringing about the dark or cloudy appearance of muscle fibers.

The two types of fibers, dark and light, the occurrence of which is well known in adult vertebrates, are also present in the muscles of the fetus.

The terms ''red and white muscle'' refer to macroscopical color differences only. Applied to the microscopic appearance of muscle fibers these terms become a misnomer if used as synonymous with ''dark and light muscle fibers.''

The interstitial granules and fat droplets of muscle are somewhat uniformly arranged in longitudinal and in transverse rows between the muscle columns. Small granules and fat droplets form transverse rows in segment *J* on either side of the membrane of Krause while those of larger size are in segment *Q*. The arrangement of the granules and fat droplets within muscle fibers is not dependent upon any connection with a fibrous net-work but is determined solely by the position of the membrane of Krause, the size of the granules, and the pressure of the muscle columns.

The true interstitial granules are of a soft, plastic substance and have no limiting membrane.

The exact chemical nature of the true interstitial granule is unknown. They are certainly not composed wholly of fat, though they contain an alcohol-soluble element. As was suggested by Regaud, they may be an albumino-lipoid.

Many fat droplets in muscle fibers are not preserved by formalin fixation. After a variable length of time in formalin fixatives the droplets may disappear. Fresh tissues must be used if all the droplets are to be demonstrated. This confirms a conclusion drawn by Bell.

Fat droplets in muscle fibers are frequently stained but faintly or left colorless by the commonly used solutions of Scharlach R and Sudan III in 70 per cent alcohol. Alkaline-alcoholic solutions of Scharlach R applied to fresh tissue stain all the fat droplets of muscle fibers. By this method preparations may sometimes be shown to be loaded with fat droplets when none are stained by the simple alcoholic solutions.

Nile blue sulphate and Nile blue chlorhydrate color all the fat droplets of muscle fibers when fresh tissue is used and stained sections are placed in alkaline water or mounted in an alkaline medium. The droplets are usually colored red, but under certain conditions they stain blue. With favorable material, pectoral muscles of pigeon and bat, after a short formalin fixation, both true interstitial granules and fat droplets may be stained in the same preparation, the former blue, the latter red.

Many fat droplets of muscle fibers are not blackened by osmium tetroxide.

For the most part the fat droplets of muscle fibers are neutral fat, glycerin esters of fatty acids. No convincing evidence has yet been presented to show that the fat droplets contain any substance other than neutral fat. They may not be pure neutral fat but it is improbable that they contain any considerable amount of albumin or other non-fatty substance.

Both true interstitial granules and fat droplets are of wide distribution in striated muscle, occurring under normal physiological conditions both in insect muscle, and also in the skeletal and cardiac muscle of vertebrates.

The physiological significance of the true interstitial granules is uncertain.

The quantity of fat in muscle fibers is increased when the animal (rat) is fed on fat meat and decreased during inanition. The fat droplets of muscle fibers are reserved food material. This conclusion was reached by Bell.

This study was conducted under the direction of Prof. Irving Hardesty and I am under obligation to him for many helpful suggestions. I am also indebted to Prof. Gustav Mann who has given me valuable assistance.

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MORBIDITY AND MORPHOLOGY.

A COMPOSITE STUDY OF THE INCIDENCE OF DISEASE AND PHYSICAL FORM IN NEW ORLEANS, LOUISIANA.

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My studies of the Filipinos while I was living in the [363] Philippines from 1907 to 1910 enabled me to classify the natives into three large general groups, depending upon their form of head, face, nose, ears, trunk and extremities. Before leaving the archipelago I associated tuberculosis with one of the groups and kidney diseases with the other two. My studies included more than 500 diseased individuals chiefly in the town of Taytay, about 30 miles from Manila, where a medical and anthropological survey was conducted under the direction of the Bureau of Science of the Philippine Government. More than 100 post mortem examinations were subsequently made at Malecon Morgue and the work done at Taytay on the living was in this way corroborated.[1]

Investigations have been continued from time to time since then in New Orleans at the Charity Hospital and the Touro Infirmary Dispensary, where more than 1000 individuals have [364] been examined. In addition to this about 100 post mortem examinations were made. My work was accomplished chiefly through the kindness of Dr. Lemann, at the Touro Dispensary, whose clinic I attended during the spring months, March, April and May, of 1911 and 1912. I examined first the general morphology of the patient and later examined the case

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[1] The results of these observations may be found in my work (Chapter VII) The Racial Anatomy of the Philippine Islanders, J. B. Lippincott Co., Philadelphia, Pa., 1910. The terms used there, Iberion, Austreloid and Primitive, are here replaced by hyper-onto-morph, meso-onto-morph and hypo-onto-morph, respectively.

[364] medically with Dr. Lemann or someone else, the diagnosis being concurred in by at least two physicians.

Only 894 of the 1000 records obtained are utilized in this study because of the absence of essential data in the remainder. Diagnosis was made of 539 diseases among the 490 colored individuals, and 445 diseases among the 404 white individuals. When it is understood that 127 negroes and only 24 whites have constipation and in the majority of these there is no other affection, it is demonstrated that the whites exhibit a slightly greater relative morbidity than the blacks, but in none of these figures are the facts significant.

It may be of interest to note the incidence of diseases and sex. One hundred per cent more men than women have tuberculosis, whereas one hundred per cent more women than men have diseases of the central nervous system. One hundred per cent more men than women have syphilis and accidents are more frequent among men than women. On the other hand there is more anemia and constipation among women than among men. These differences may be incidental to habits, or merely accidental variations, without significance.

The white and colored elements of the hospital population here represented exhibit evidences of morbidity in different directions, as indicated in the following table, in percentages.

TABLE I.

WHITE MORBIDITY PREDOMINANT.

	Pulmonary Tuberculosis	Nervous System	Digestive System	Arthritis	Emphysema	Anemia
White ..	19	13	5	5	3	3
Colored .	9	5	2	1	1	0.2
Total ...	14	9	4	3	2	2

COLORED MORBIDITY PREDOMINANT.

	Constipation	Venereal	Cardiac and Renal	Pleurisy	Aneurysm	Asthma	Trauma
White	5	11	8	1	1	0.6	3
Colored ...	25	23	10	2	2	1	4
Total	15	17	9	2	2	1	4

OTHERS.

	Acute Infections	Arterio-Sclerosis	Others
White	10	4	10
Colored	10	3	4
Total	10	4	7

It is to be seen from this table that the whites have more [364] pulmonary tuberculosis, diseases of the nervous and digestive systems, arthritis, emphysema and anemia, whereas the blacks have more constipation, venereal diseases, diseases of the cardiac and renal systems, pleurisy, aneurysm, asthma and traumatic affections, the two having about an equal share of infectious diseases and arterio-sclerosis. The whites have the most of the remaining diseases.

The differences noted are of interest because of the differences in morphology and cultural conditions of the two peoples. The excess of constipation among the colored people is not necessarily an indication of greater susceptibility on their part, but represents their greater ignorance regarding the value of keeping the bowels open and the use of proper means to secure that effect. Neither can the greater extent of venereal infections among the colored people be attributed to greater susceptibility on their part, because the extent of venereal infections among a people is considered to be due directly to the freedom of sexual intercourse—promiscuity. We may infer, therefore, that greater freedom exists among the negroes than among the whites, which condition is acknowledged to be true by all competent observers. So prevalent is venereal infection among them that the question asked the colored people in taking histories in the New Orleans hospitals is not "Did you ever have" the infection, but "When did you have" it.

There are two significant conditions, however, that indicate structural or physiological differences rather than differences in cultural conditions. These are that the whites have more affections of the lungs, of the nerves and of the alimentary canal, whereas the blacks have more affections of the circulatory and renal systems. These differences may be attributed by some observers to physiological causes and may be due to occupation, habit, or other activities of body or mind. One may say that the heart, arteries, veins and kidneys of the colored people are more susceptible to disease than other parts of the system because of the greater stress of manual labor and the excessive sexual exertion on their part; whereas, the brain, nerves, stomach, intestines and lungs of the white

[364] people are more susceptible to disease because of greater mental activity and sedentary occupations. The out-of-door activity of the negroes in laborious occupations involving stress and strain of the connective tissue structures undoubtedly produces a greater number of traumatic cases, may affect the heart and kidneys and possibly induces a relative freedom from tuberculosis. But there are fundamental differences in morphologic structure that may account for these differences in susceptibility of the two peoples, and the differences in structure are based on the two fundamental embryonic tissues, mesothelium and epithelium; the lungs, nervous system and alimentary canal derived from epithelium, the heart, circulatory system and kidneys derived from mesothelium. Certain types regardless of race, color, or cultural conditions may be called mesothelial types, while others equally distinct may be called epithelial types. The mesothelial types are greatly developed in bone, muscle and other connective tissues, whereas the epithelial types are less developed in this way, are more developed in brain, lungs and alimentary canal. Great development of either class of tissue seems to weaken it and make it more liable to disease, therefore the two types may be called *epitheliopath* and *mesotheliapath.* The latter is the meso-onto-morph, the former the hyper-onto-morph. But I am going ahead of my subject.

While in the Philippine Islands, I noticed a difference in
[365] susceptibility after I had segregated the types. This occurred in the following way. All unclaimed bodies in the city of Manila are brought to the morgue connected with the medical department of the University of the Philippines where they may be utilized for anatomical purposes. I selected the thin subjects for dissection for two reasons, because they dissect with greater ease and they take injections better. On examination it was found that they had usually died of pulmonary tuberculosis, their arteries were elastic and free from signs of arterio-sclerosis, and their connective tissues, muscle and bone were poorly developed and fragile. Such subjects were invariably of the hyper-onto-morph form, the epithelial type, the epitheliopath. At that time I associated the type with susceptibility to tuberculosis, but since then I have found that

all the epithelial structures seem to be more liable to disease. [365] The meso-onto-morph on the other hand is more liable to diseases of the mesothelial tissues.

One unexpected feature of the two forms is that the hyper-onto-morph has a short intestine, 12 to 15 feet, whereas the meso-onto-morph has a long intestine, 20 to 25 feet. I have frequently amazed my students by predicting the length of the intestine before the body was opened, which I did by previously examining the ears of the individual.

I have devised a system of descriptive morphology and have used it in racial anatomy to differentiate morphologic forms. The most exact anthropologists decree that nothing shall be accepted that is not exactly measured or defined, yet there are certain qualities which can be described more accurately than they can be measured. My work is on the order of zoölogy applied to man and is the method of the naturalist rather than the mathematician.

Man's form may be classified by means of the external ear, physiognomy and body parts in three fundamental physical forms. The three fundamental forms represent stages of evolution in the race as well as degrees of growth in the individual, and I have used the terms: hypo-phylo-morph, meso-phylo-morph and hyper-phylo-morph to designate three stages of the former and the terms hypo-onto-morph, meso-onto-morph and hyper-onto-morph to designate three degrees of the latter.

The hypo-onto-morph is usually small in stature and fat, with short legs and arms, chubby hands and feet, and relatively long trunk, the characteristic form of childhood predominating. The head is round, broad and short, and large in relation to the stature of the individual, the total head height from chin to vertex being 1/6 to 1/7 of the total stature, the normal for the European being about 1/8. The face is ovoid, with small forehead and chin, wide cheeks, and is very broad and short, often dished or depressed about the nose—flattened in front—and the face below the eyes is small compared to the size of the head, as in the infant. The nose is flat, broad and short, with depressed, flattened bridge, upturned tip, and the nostrils open forward rather than down-

[365] ward. The eyes are often narrow slits and the eyelids are "puffed" as if infiltrated. The cheeks appear as if they had chestnuts in them thus completing the infantile appearance. This form is found largely throughout the Orient and is a fundamental Malay or Mongolian type. Modified forms similar to this are found elsewhere, especially among the Africans and not a few among the Europeans.

The meso-onto-morph is of medium size and stockily built. The extremities are relatively long, the feet and hands large and the trunk is short. The head and face are ellipsoid, and large compared to the size of the head. The malar and zygomatic bones are prominent, the nose is massive, long, wide and high, with depressed root, straight bridge and nostrils that open downward and forward. This is the fundamental African form but is also found extensively in Europe where it has undergone modification, and it is not unknown in the Orient.

The hyper-onto-morph is either tall and slender or small and delicate. The trunk and extremities are intermediate in length between those of the other two, and the face is also intermediate in size and pentaganoid or triangular, with broad forehead and small chin. The total head height from chin to vertex is less in this form than in the other two, about 1/8 the total stature, the European artist's ideal. The head is large in proportion to the size of the face below the eyes. The head is long and narrow, and the nose is also long and narrow, with high root and bridge, and the nostrils open downward. The eyes are wide open and close together, in contradistinction to those of the hypo-onto-morph, which are semiclosed and far apart. This is the fundamental European form, although their dispersal through migrations, both historic and prehistoric, has taken them to almost all parts of the earth.

From the phyletic standpoint the European represents the present day product of what was originally the hyper-phylomorph, although occasional mixtures with the hypo-phylomorph and the meso-phylo-morph have occurred. The African represents the meso-phylo-morph in the same way, and the

Oriental the hypo-phylo-morph, each having mixed to some [365] extent with the other two forms.

The terms hypo-, meso-, and hyper-phylo-morph might have been retained instead of using the terms hypo-, meso-, and hyper-onto-morph but I preferred the latter as more specific and because they refer to individuals rather than peoples. The hyper-onto-morph, etc., is then the living representative individual of what was once the hyper-phylo-morph, etc., and retains the original form to some extent, but may have black skin and kinky hair among the negroes, black skin and straight hair among the East Indians, ruddy skin, blonde hair and blue eyes among the North Europeans and tanned skin, black hair and dark eyes among the South Europeans or Mediterranean peoples. In other words I believe the form to be more fundamental than the pigment or hair structure.

It cannot be denied that forms similar to those described under the three heads hypo-, meso-, and hyper-onto-morph may be due to the effects of individual development, or the environment during one generation, in other words, ontogeny, but in general I believe the three forms are relics of previous phyletic forms. Individuals may also be seen who have one or more of the characters of one form, but otherwise are of one [366] of the other two forms, and this may be attributed to mixing, but is more apt to be a matter of individual development—ontogeny.

The characteristics heretofore given are those usually described by morphologists, but my classification is based more upon ear form than any other factor. The form of the external ear, or pinna, should be more unchangable than any of the characteristics previously given because it is not so liable to physiological and selective influences, and because it is fundamentally cartilage, which, as the ground work for bone, should be the most stable of tissues.

The human ear may be described as consisting essentially of two parts, the external border, or helix, with its lower end, the lobule; and the central part, or concha, with the tragus and antitragus. The outer border of the concha is also the inner border of the helix and it is called the anthelix. The tragus is the small nodule immediately in front of the ear

[366] hole, or external auditory meatus, and the antitragus, which is opposite the tragus, is the lower end of the anthelix. Darwin's tubercle is to be seen on the upper part of the helix on the inside of its overturned margin near the top of the pinna. It represents the tip of the ear which has turned in towards the concha during the growth of the fœtus before birth. The pinna is at first formed flat in the embryo and at the fourth month of intrauterine life there is a tip at the upper outer margin of the helix. At this time the ear of the fœtus resembles that of the monkey, *Macacus rhesus,* with its pointed tip extending upward and backward. Later in the development of the fœtus the ear is reduced in size by the rolling in of the tip and of the entire helix, accompanied by a protrusion of the anthelix system including the tragus and the antitragus. When the adult human ear has attained its full maturity the rim of the helix has rolled inward and forward and the tip becomes Darwin's tubercle.

We may conceive that the first or earliest form of the ear after the fourth month of fœtal life is one in which the helix has rolled in, but the anthelix system, including the rim of the concha, the tragus and antitragus, has not projected far out from the head. In this condition the ear would have the form of a half bowl, and would be semi-trumpet shaped. This is the condition of the hypo-phylo-morph ear. Should the ear continue to develop it would assume the shape found in the hyper-phylo-morph, when the ear is flatter with the anthelix system at times projecting beyond the helix, and the latter turned backward towards the head. The tragus and antitragus would then project, and the lobule would be close to the head. The form of the meso-phylo-morph is somewhat intermediate between the other two, but is a distinct type nevertheless.

The hypo-onto-morph ear is usually small and round, the helix is turned in and forms a heavy roll at the rim of the ear extending downward into the lobule which turns almost horizontally to form a shelf-like lower border to the ear. The anthelix is almost parallel to the helix and is about the same size because the helix has rolled in until it has almost covered the anthelix, the two looking like a double roll surrounding the concha. The latter is deep and wide like a bowl or trumpet. The tragus and antitragus do not project beyond the helix but are turned in or depressed. The upper half of the helix turns over to form a shelf, like that of the lobule, and between the two is a part of the helix which does not project as much as the other parts. The hypo-onto-morph ear is usually thick and coarse, with rounded edges, and skin lines that are large and far apart, with large ridges between them. [366]

The hyper-onto-morph ear stands in a contrast with the ear of the hypo-onto-morph. It is thin, long, delicately molded, and the helix is very slightly rolled in, being a mere margin rather than a heavy roll. The distance between the helix and anthelix is great above, and the helix disappears below except for a flat surface with a margin which merges into the lobule that is often absent, the helix then passing diagonally downward directly into the cheek. The concha is long vertically, and its border, the anthelix, projects so much that viewed from behind or in front it seems to be further away from the head than the helix. The tragus and antitragus point outward and often project beyond the helix. Looked at from behind, the rim of the helix presents the shape of the italic letter *f* or the old English letter ſ, and seems to have been seized between the thumb and forefinger and twisted upward and backward. The helix is therefore closest to the head at its lower extremity, the lobule, and also at the point where Darwin's tubercle should appear: and it is further away from the head at its summit, also at a point immediately behind the concha. This gives a wavy or spiral effect to the helix, which is very characteristic of this form of ear. The ear is thin and the lines are fine and close together.

The meso-onto-morph ear is somewhat intermediate between the other two forms although it has distinctive characteristics. It is large, heavy-looking and soft, more nearly flat than either of the other forms, and it has a lobule that forms a sloping shelf. The rim of the helix is large, oval and heavy looking. The ear is a large shallow bowl, with sides broad and flat, and a rim heavy but not rolled in very much.

The stability and permanency of the ear form have enabled me to classify types that would otherwise have been almost,

[866] if not absolutely, impossible of classification. The form of the face and head are molded by the development of the teeth, the enlargement of the bony sinuses around the nasal chambers, by the action of the muscles of mastication and by the extent of the erectile tissues of the nasal cavities, as well as by the action of the facial muscles through the expression of the emotions; but the ear form is laid down in cartilage, a stable tissue, it is not so prominent as the eyes, nose and mouth, and not so liable to natural and sexual selection, nor is it subject to physiological influences as other features, therefore, it has remained constant in form while other structures have undergone greater variation. The ear form has probably remained constant throughout tens of thousands of years since the three types became fixed, and in the mixtures of the different forms due to interbreeding the ear retains its
[867] original characteristics to a great extent, and is found pure in the greatest variety of peoples in all parts of the world.

In a comparison of the dispensary negro population, or the negro patients of the Touro Free Dispensary, with the general negro population, or the negro people on the streets of New Orleans, it is found that the difference is as follows:

TABLE II.

	Hyper-	Meso-	Hypo-
City Streets	48%	45%	7%
Dispensary	71%	24%	5%

The hyper-onto-morph has a greater morbidity and this is coincident with the great number of the mulatto or light colored element among the negroes.

The hyper-onto-morph among the whites apparently has not a greater morbidity, because the percentages of the three forms on the streets of New Orleans and in the dispensary are practically identical:

TABLE III.

	Hyper-	Meso-	Hypo-
City Streets	80%	18%	2%
Dispensary	80%	19%	1%

The percentages of all forms in the total of the 894 cases utilized in this study are as follows:

TABLE IV.

	Hyper-	Meso-	Hypo-
White	76.6%	21.2%	1.6%
Colored	45.0%	49.0%	6.0%
Total	59.4%	36.3%	4.3%

Further analysis of the colored people given in Table 4 reveals the following figures:

TABLE V.

	Light Colored	Neutral Brown	Sooty Black
	39%	44%	17%
Hyper	55%	42%	28%
Meso	39%	51%	64%
Hypo	6%	7%	8%

The significant facts here are that with an increase of pigmentation there is an increase of the hypo- and meso-onto-morph, and with a decrease of pigmentation there is an increase of the hyper-onto-morph. The light colored negroes include several albinos and all the octoroons, quadroons, mulattoes and sambos. The lighter color is due to recent mixtures of negro and white, and the darker colored are of purer African extraction. The indication is that the white is hyper-onto-morph and the negro is meso-onto-morph with some hypo-onto-morph.

Comparing Table 2 with Table 4 a discrepancy in the percentages of dispensary negroes will be noticed. This is due to the fact that negroes of all the clinics, including nervous diseases, eye, ear, nose, throat and genito-urinary diseases are included in Table 2, whereas only medical clinic cases are included in Table 4. The fact that more hyper-onto-morphs are found among the dispensary negroes of Table 2 would indicate that the hyper-onto-morph is more susceptible to nervous diseases, eye, ear, nose, throat and genito-urinary diseases than are the other two forms. This is undoubtedly true and will be demonstrated in part in the subsequent consideration of the diseases in detail.

In any consideration of this study it must be borne in mind that the personal equation is to be considered. A diagnosis

[367] is often overlooked because it is not looked for, but where the diagnosis is given it is self-sufficient evidence. The omission of a diagnosis cannot well apply to tuberculosis, however, because I was on the lookout for this disease in an effort to determine exactly, if possible, the physical type with which it is associated. Observations in the Philippines had convinced me that the disease is especially virulent among the hyper-onto-morphs. This has been confirmed both among the whites and among the colored people of New Orleans. Whatever else may be the result of this investigation the most emphatic substantiation of previous observations is here presented. If other facts are significant they stand for themselves, no effort has been made to prove or disprove them.

Each disease will be discussed here in turn, in relation to the three physical forms previously described.

PULMONARY TUBERCULOSIS.

One hundred per cent more white than colored persons came to the Touro Dispensary afflicted with pulmonary tuberculosis among the 894 individuals examined, but this may be of no great significance, only the chance distribution in a random sample of the city sick; another thousand individuals might show a different proportion altogether. Neither does the one hundred per cent excess of males of both races who have tuberculosis, present any great significance, although both proportions are true and either may be significant. White people may be more susceptible to tuberculosis than colored people, and males may be more susceptible to tuberculosis than females, but this can be determined only by many thousands of records from all parts of the world and under all conditions of life.

When, however, practically every individual who is afflicted with tuberculosis, white or colored, male or female, is of one type, a type more distinct than any other human type, readily separable from the other types by differences in ear form, physiognomy and the length relations of body parts, then one comes to realize that less than a thousand individuals taken as a random sample of the city sick is sufficient to determine the susceptibility of such a type to tuberculosis. This type is

the hyper-onto-morph, the slender individual, with long head, [867]
face, nose and extremities, and ear with everted tragus, and
antitragus, and anthelix, and with rolled out helix. Only two
individuals of the 134 afflicted with tuberculosis had no trace
of the hyper-onto-morph form. No. 8797, white male, age
55, a modified meso-onto-morph with kyphosis, bronchitis and
acute indigestion, and No. 47, white female, age 47, a modified
meso-onto-morph with sacro-iliac subluxation. The remainder
of those who have pulmonary tuberculosis are pure
or mixed hyper-onto-morphs. In confirmation of this I have
records of 38 post mortem examinations of individuals found [868]
to have tuberculosis, of whom there are 11 white hyper-onto-morphs, 23 colored hyper-onto-morphs, 4 colored meso-onto-morphs, and 1 colored hypo-onto-morph. It cannot be said that no other form except the hyper-onto-morph will have tuberculosis, nor can it be said that all hyper-onto-morphs will have tuberculosis, but it can be said that the hyper-onto-morph is susceptible to tuberculosis. Small, slender, hyper-onto-morphs with small, round, everted ears were found with tuberculosis most frequently. Tall, slender, hyper-onto-morphs with everted ears that have no lobule are also susceptible and often have the most aggravated type, cavity formation with bronchiectasis.

Blondes as well as brunettes of the hyper-onto-morph form have the disease, but very few blondes are recorded, probably because of the preponderance of brunettes in New Orleans. There were a few cases like the following, however:

White German-American, blonde, male, age 23. Cough and expectoration for two months. Pharyngitis, laryngitis and signs of incipient pulmonary tuberculosis.

White, blonde, female, married, age 30. Hacking cough for one year, hoarse at times, and free expectoration. Has lost 30 pounds weight in the past 18 months. Dullness at the left apex with bronchial breathing and subcrepitant râles over this area.

The form of hyper-onto-morph that is believed to represent the primordial or original prehistoric type of hyper-onto-morph, is susceptible to tuberculosis but is very resistant to a fatal issue with the disease. This form of hyper-onto-morph

[868] is similar to the early cave man of Europe known as the Cro-Magnon race, and is intermediate between the Mediterranean form of the hyper-onto-morph, and the meso-onto-morph. This Cro-Magnon form of the hyper-onto-morph is tall, raw-boned, with large face—long and wide—prominent cheek bones and large nose and long everted ears with pendant lobules, and is distinctly different from the Mediterranean form of the hyper-onto-morph who is small, slender, thin, dark, with small face, long, thin nose and face, and ears of the everted form, although they are both similar especially in ear form. The Mediterranean race has been derived from forms similar to the Cro-Magnon race through life in cities, tropics, semitropics, etc., and may be only the attenuated form as a result of deficient nutrition, etc., incident to this life. The early form of hyper-onto-morph (Cro-Magnon) is at present more resistant to tuberculosis than the derived form (Mediterranean). A few illustrations will suffice.

No. 2287. White male, age 55. Hyper-onto-morph (Cro-Magnon). History of tuberculosis for 20 years, beginning with spitting of blood. At present emaciated, emphysematous, with pigeon-breast. Dullness over left infraclavicular region 4½ x 8¾ inches in area. Dullness at both apices and to angle of scapulæ behind. Râles below scapulæ. Temperature 97° to 99.5° F. Lost 2 lbs. in 3 years. Progress favorable.

No. 6487. White male, age 64. Hyper-onto-morph (Cro-Magnon). Was treated for pulmonary and laryngeal tuberculosis in the Touro Dispensary in 1907. Condition at present: Fair nutrition, process in lungs still limited to right apex. Dullness, bronchial breathing, squeaks in supraclavicular region. Few subcrepitant râles in infraclavicular region. Larynx shows no signs except slight roughening of plicæ interarytenoideæ.

No. 6616. White female, age 61. Hyper-onto-morph (Cro-Magnon). Was tested for pulmonary tuberculosis in Touro Dispensary in 1908. At present emaciated. Kyphosis. Scoliosis. Both apices involved. Temperature 99.3° F.

No. 6980. Colored (sooty black) male, aged 52. Hyper-onto-morph (Cro-Magnon). Four months previous had had one rib broken and two "strained." Spat blood for two days. Has since lost about 20 lbs. in weight. At present there is dullness at left apex posteriorly, with increased vocal fremitus over this area.

No. 7061. Mixed Negro-Indian female, age 57. Hyper-onto-morph (Cro-Magnon). History of fever, heavy cold, profuse expectoration, loss of weight, no appetite, bowels costive. At present emaciated, a few scattered râles over left side, where there is a peculiar grating sound with râles intensified over the 3d rib. Tubercle bacilli are present in the sputum. [868]

No. 103. Benito, male Chinaman, age 88. Hyper-onto-morph (Cro-Magnon). Charity Hospital. Pulmonary tuberculosis.

These examples will suffice to show that the types are not racial but anatomical, and that the individuals attain an advanced age in spite of the tuberculosis.

There can be no doubt that the hyper-onto-morph of all kinds is susceptible to tuberculosis, and although the tendency may be aggravated by unhygienic conditions, it is largely responsible for the prevalence of the disease.

Diseases of the Nervous System.

The diseases of the nervous system may be enumerated as follows: Neurasthenia 33 cases, paralysis (all kinds) 18, exopthalmic goitre 12, insanity 6, epilepsy 5, pellagra 5, tabes dorsalis 2, angioneurotic edema 2, sclerosis 1, herpes zoster 1, hysteria 1, torticollis 1, 87 in all. Of these 79 are hyper-onto-morphs, 6 are meso-onto-morphs and 1 a hypo-onto-morph, the last the individual with multiple sclerosis. Of the 6 meso-onto-morphs 2 have epilepsy, 1 paralysis, 1 pellagra, 1 hysteria and 1 neurasthenia. Notable is the fact that all the insane and those with exophthalmic goitre are hyper-onto-morphs.

There can be no doubt that the hyper-onto-morph is susceptible to diseases of the central nervous system.

Diseases of the Alimentary Canal.

The diseases of the alimentary canal are the following: Constipation 161 cases, stomach 14, diarrhœa 6, typhoid fever 5, intestinal parasites 4, and appendicitis 2, 192 in all. Constipation cannot be said to have an affinity for any one form because 49 cases are meso-onto-morphs, 39 hyper-onto-morphs and 1 hypo-onto-morph, the remainder being mixed, 60 of the hyper-meso form and 13 of the hypo-meso form. The forms that have other alimentary troubles are 30 hyper-onto-morphs and 1 meso-onto-morph. Of stomach troubles 9 are simple

[368] such as gastritis, 4 are carcinoma, and 1 gastritic ulcer. All are hyper-onto-morphs. Post mortem examination of 3 individuals, dying of carcinoma, of the hyper-onto-morph class was made. Except for constipation, gastro-intestinal diseases pertain to the hyper-onto-morph. There are only 31 cases, however, which is a small number for generalization, but the indi-
[369] cation is that the hyper-onto-morph is susceptible to diseases of the alimentary canal, although this is not so emphatic as for tuberculosis and the nervous system.

CARDIAC AND RENAL DISEASES.

Affections under this head include those of the heart, circulatory system and kidneys, arterio-sclerosis and aneurysm. Affections of the heart and kidneys are grouped as one complex but arterio-sclerosis and aneurysm will be discussed separately.

Ninety-two individuals were diagnosed with heart or kidney troubles, and of these 80 are meso-onto-morphs, 11 are hyper-onto-morphs and 1 is a hypo-onto-morph. As will be noticed only 12 individuals had no indication of the meso-onto-morph form. Three of the hyper-onto-morphs have tuberculosis associated with the cardiac or renal condition and 4 are advanced in age. The inference is that the meso-onto-morph is most susceptible to cardiac and renal affections.

Arterio-sclerosis claims 24 meso-onto-morphs, 11 hyper-onto-morphs and no hypo-onto-morph, although 3 meso-onto-morphs have traces of hypo-morphism. The majority of the hyper-onto-morphs are well advanced in age, beyond 50 years, and this may account for the great proportion of them with arterio-sclerosis. The meso-onto-morph is most susceptible to this disease.

Fifteen meso-onto-morphs have aneurysm, only two hyper-onto-morphs (modified) and none of the pure hypo-onto-morphs have this affection, although 6 of the meso-onto-morphs have some hypo-morphism. Aneurysm, therefore, seems to strike the meso- and hypo-onto-morphs.

Post mortem examination of 17 individuals with cardiac or renal troubles gives 15 meso-onto-morphs and two modified hyper-onto-morphs. Seven other individuals with extremely dilated aorta are meso-onto-morphs. There can be no doubt [369] of the association of heart and arterial affections with the meso-onto-morph and the kidney affections may be incidental to these.

Emphysema, Asthma and Pleurisy.

Contrasts and parallels enter here. Emphysema affected 12 hyper-onto-morphs and 4 meso-onto-morphs. Pleurisy attacked the same, whereas asthma attacked 6 meso-onto-morphs and two hyper-onto-morphs. Emphysema affected 12 white persons and 4 negroes, whereas the other two attacked 16 negroes and 7 white persons. The numbers are too few for generalizations yet they are suggestive. The negro may be susceptible to pleurisy yet the form of the negro most susceptible is the hyper-onto-morph. The negro likewise may be susceptible to asthma, yet the form of the negro most susceptible is the meso-onto-morph. The white people may be susceptible to emphysema, yet the form most susceptible is the hyper-onto-morph. That the meso-onto-morph appears to be susceptible to asthma may throw light on the nature of the disease. The indication is that its muscular nature is paramount. Post mortem examination of 19 subjects with pleural affections reveals 11 hyper-onto-morphs, 7 meso-onto-morphs and 1 hypo-onto-morph.

Arthritis.

Arthritis deformans claims 13 hyper-onto-morphs and 2 meso-onto-morphs; simple arthritis claims 12 hyper-onto-morphs and 2 meso-onto-morphs, one of which is mixed with hypo-onto-morph, therefore a greater tendency to arthritis on the part of the hyper-onto-morphs is evident.

Anemia.

Every anemic individual observed is a hyper-onto-morph, 14 in all, including 1 with pernicious anemia.

Eye Troubles.

Every individual with affections of the eye is a hyper-onto-morph, 5 of whom are white and 5 colored.

VENEREAL DISEASES.

The relative proportion of the different forms infected with venereal disease is almost exactly the same as the relative number of the different forms in the total number examined, therefore no inferences may be drawn. There seems to be, however, a greater tendency on the part of the hyper-onto-morph to syphilis. There are 31 hyper-onto-morphs to 14 meso-onto-morphs with syphilis, whereas there are 24 hyper-onto-morphs to 17 meso-onto-morphs with other affections of the genito-urinary apparatus.

TRAUMATIC.

Accident cases include a large number of sacro-iliac subluxations, of which all among the white people are hyper-onto-morphs, whereas 11 of the 13 among the colored people are meso-onto-morphs. This is another way of saying that the white people are hyper-phylo-morphs and the colored people are meso-phylo-morphs to a large extent. Other accident cases are distributed among the three forms in about the normal proportion.

ACUTE INFECTIOUS DISEASES.

These include the following cases not before given:

Bronchitis 14, malaria 10, rheumatism 6, tonsilitis 10, coryza 6, jaundice 5, measles 3, mumps 2, cystitis 3, boils 1, endocarditis 1, pneumonia 1, influenza 1, septicemia 1, sore throat 1, 64 in all, of which 36 are hyper-onto-morphs, 23 meso-onto-morphs and 5 hypo-onto-morphs. The last is a higher proportion than normal, the other two have about the usual proportion. It may be that the hypo-onto-morph is susceptible to acute infections, but this is only suggested, not proved.

The other diseases are so few in number and so diverse in form that deductions would be unfair.

INFERENCES.

The present study has demonstrated that morphologic entities which may be called character-complexes may be distinguished by their ear form, physiognomy and body parts. Three definite forms may be segregated from any group of people, and these three forms I have designated hypo-onto-morph, meso-onto-morph and hyper-onto-morph, depending upon their apparent position in the scale of evolution or development—their ontogenic position. [370]

The hypo-onto-morph may be susceptible to acute infectious diseases and cardio-renal affections, but their number is too few for final judgment.

The meso-onto-morph is susceptible to disease of the tissues derived from mesothelium, especially to diseases of the circulatory system and kidneys.

The hyper-onto-morph is susceptible to diseases of the tissues derived from epithelium, especially to pulmonary tuberculosis and diseases of the alimentary canal and central nervous system.

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ON MAKING SERIAL CELLOIDIN SECTIONS AND A STAIN FOR THE INTERCALATED DISCS OF CARDIAC MUSCLE

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I. A METHOD FOR MAKING SERIAL SECTIONS IN CELLOIDIN

Although several methods are now in use for making serial sections from celloidin blocks, all of them are more or less slow and involve some unnecessary manipulation. The method herein given is a modification of the celloidin sheet method for paraffin sections suggested by Huber[1] and of the Weigert method for making serial sections in celloidin.[2] It has given satisfactory results in my hands. In detail the method is as follows:

Select plates of glass of suitable size, say 5 by 7 inches, and thoroughly cleanse them. Coat one surface of the glass with the following solution and allow it to dry:

Saccharose-dextrin solution

Saccharose	3 grams
Dextrin	3 grams
Distilled water	100 cc.

Add a crystal of thymol to this solution to prevent fermentation and the growth of fungi.

After the above solution has thoroughly dried on the plate, it is then coated with a 4 per cent solution of celluloid in acetone. I have used coatings made with celloidin but do not find them as satisfactory for the following reasons:

(1) Celloidin sheets are more fragile and thus more easily torn. (2) Celloidin sheets stain by many of the dyes, whereas

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[1] Huber, G. Carl, Laboratory work in histology, p. 31, 1900.

[2] Wiegert, C., Zeitschr. für Wiss. Mikros., Bd. 2, 1885, p. 490.

celluloid does not. (3) Celloidin sheets are not as transparent as celluloid sheets. (4) These celluloid sheets may be made up and kept on hand for future use, dried if desired, while celloidin sheets cannot, for the celloidin will crack upon drying.

When the sections are cut, they should be placed on the celluloid sheets in the desired order and should be moistened from time to time to keep them from drying out. After the plate is filled with sections, it should be blotted with a smooth surfaced toilet paper to remove the excess of alcohol. The surface should now be sprayed with a 1 or 2 per cent solution of celloidin in equal parts of ether and absolute alcohol, to cause the sections to adhere to the celluloid sheet. The spraying is best done by the aid of an atomizer. Allow this to dry partially, then immerse the plate containing the sheet in 70 per cent alcohol and then in water. The water will dissolve the saccharose-dextrin solution and the celluloid sheet containing the sections will then float off. The sheet may now be preserved in 75 or 80 per cent alcohol and stained at some future time, or, it may be passed through the staining reagents at once and finally cleared in any clearing fluid suitable for celloidin sections. The sections are now separated into strips of the desired length by means of a roller-paper cutter, or cut apart with a sharp knife, and mounted in their serial order on slides properly numbered so as to keep the sections in continuous series.

II. ON STAINING THE INTERCALATED DISCS IN CARDIAC MUSCLE

J. L. Bremer recommended[3] Mallory's phosphotungstic acid hematoxylin for the staining of intercalated discs in heart muscle. I find that by Bremer's method the striations and intercalated discs stain well, but to get a good nuclear stain it is necessary to stain longer and by so doing the preparation is made too dark. With the method given below I have had good results.

1. Fix in Zenker's fluid or saturated aqueous mercuric bichloride. Formalin will do but the results are not so good as after either of the above fixing agents.

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[3] Anat. Rec., July, 1910.

2. Wash, dehydrate, and embed in either celloidin or in paraffin.

3. Cut thin sections and bring them down to distilled water.

4. Deeply overstain (6 to 24 hours at room temperature) in a well ripened solution of either Mallory's phosphotungstic acid hematoxylin or phosphomolybdic acid hematoxylin. The same results may be more quickly obtained by placing in the paraffin oven at 45° or 50°C. for from forty-five minutes to two hours.

5. Wash in water and place in a 0.25 per cent solution of potassium permanganate until the blue black stain begins to turn brown. This time varies from two to fifteen minutes, depending on the length of time the sections remain in the hematoxylin.

6. Wash hastily in distilled water to remove excess of potassium permanganate and transfer to a 1 per cent aqueous solution of acid potassium sulphite until the preparation assumes a steel-gray cast. If the preparation now be cleared and looked at under the microscope, it will be found that only the intercalated discs are stained. I have found that the desired decolorization is more readily accomplished and have obtained a sharper and deeper differentiation of the discs in sections stained with phosphomolybdic acid hematoxylin than with phosphotungstic acid hematoxylin.

7. Wash the sections with water and place in Mayer's acid hematein for five minutes, to stain the nuclei. I add hematoxylin to Mayer's formula instead of hematein. I like it better because it stains the nuclei more deeply.

8. Wash well in tap water or in distilled water to which a trace of ammonium carbonate or hydroxide has been added.

9. Place in a 1 per cent aqueous solution of eosin or erythrosin for ten or fifteen minutes.

10. Wash in water, dehydrate, clear, and mount in balsam.

In well stained preparations, the nuclei are stained deeply blue, the muscle fibrillae red and the intercalated discs stand out sharply as a deep blue black.

The formulae for the stains used are as follows:

Mallory's phosphotungstic acid hematoxylin

Hematoxylin	0.1	gram
Distilled water	80	cc.
10 per cent aqueous phosphotungstic acid	20	cc.
Peroxide of hydrogen (U. S. Ph.)	0.2	cc.

Mallory's phosphomolybdic acid hematoxylin

0.5 per cent aqueous phosphomolybdic acid	200	cc.
Hematoxylin	1.75	gram

Mayer's acid hemalum

Hematein (or hematoxylin)	1	gram
90 per cent alcohol	50	cc.
Alum	50	grams
Water	1000	cc.
Acetic acid (glacial)	50	cc.

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THREE FORMS OF THE HUMAN NOSE

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The three most distinct forms of the human nose appear characteristically in different parts of the earth and the forms are clearly geographical, evolutional, and developmental. The first of the three is the under-developed nose resembling that of the infant, and this form has been called by me the 'hypo-phylo-morph;' the second is a massive nose, the 'meso-phylo-morph;' and the third is the thin, high, long, narrow nose, the 'hyper-phylo-morph.'

The hypo-phylo-morph nose is flat, broad, and short; with flat depressed bridge, upturned tip, and the nostrils open forward rather than downward. The nostrils flare and are wide open, and the extremity of the nose is uplifted or tilted back so that an instrument may be inserted horizontally along the floor of the nasal fossa without interference by the alae. The nasal ridge, or the bridge of the nose, is flat, because the nasal bones do not form a steep roof over the nasal passages by their apposition along the median line. The articulation of the nasal bones with the frontal bone is a gentle curve and not an abrupt transition. The supraorbital ridges and glabella are not prominent, nor the frontal sinuses large in association with this form of nose, but the cheeks are full, and the eyes prominent, therefore the front of the entire face is somewhat flat, although the lips project from a small mouth. The hypo-phylo-morph nose is essentially the nose of the infant.

The hypo-phylo-morph nose is found especially among the Malays and Negritos, as they exist today in the Malay peninsula, Java, Sumatra, Borneo, Celebes, and the Philippine archipelago, as well as among the Pigmies, Bushmen and Hottentots of Africa. It is also found in a modified form in Burma, Siam, Cambodia, Tonkin, Annam, in India, China, Japan, Mongolia, and among the true negroes of Africa and America. The form dwindles away through Siberia, Lapland, Finland and Russia into Europe, where the hyper-phylo-morph nose appears. The form also dwindles away through the Eskimos and Indians of the Americas, among the Polynesians and the other inhabitants of the Pacific Islands, and among the pseudo-negroes of north and east Africa, in all of which peoples the meso-phylo-morph nose appears. The hypo-phylo-morph nose is most emphatic among the women of all the countries where it appears, but is also to be seen among the men.

The meso-phylo-morph nose is massive, long and broad, not very high, with apparently depressed root due to overhanging brows and glabella: it has a straight bridge, and nostrils that open downward and slightly forward. The outlines of the nose are usually straight. Looked at from in front, the lines of contact of the nose with the face on each side are straight, and slant away widely from the inner angles of the eyes to the alae of the nose. Looked at from the side the bridge of the nose is straight or very slightly aquiline from root to tip, and the lower border (base) of the nose is straight from a point just over the akanthion to the tip of the nose, although the tip may sometimes dip below this straight line. This line is not long in relation to the breadth of the nose, but it is absolutely as long as the same line in the hyper-phylo-morph nose, and may be even longer when the nose is unusually large. The nose looks flat, due to its great breadth, when it is actually a high nose. The alae flare little although the apertures of the nostrils are large, due to the great width of the nose. The nasal bones form a more acute angle at their apposition than in the hypo-phylo-morph nose, and they pass abruptly above into the frontal bone, where the overhanging brows and the glabella give the root of the nose a depressed appearance. The malar and zygomatic bones are large and project, and the jaws are prominent both in front and at the sides of the face. The orbits are large, the bony sinuses about the nose are of great size and the lips are thick. The result is that the whole face is large, and the nose conforms with its surroundings.

The distribution of the primary forms of the meso-phylo-morph nose center among the inhabitants of the Deccan and Ceylon, among the Polynesians and the inland tribes of the Philippine Islands, Java, Sumatra, Borneo, and Celebes, and it assumes its most exaggerated form among the Tasmanians, Australians, Melanesians, pure Negritos, and true negroes. The form exists somewhat modified among the peoples who have the hypo-phylo-morph nose, and is especially emphatic among the men, although it appears among the women. It fades away through northern Asia, in central Europe, through southern Asia towards the Mediterranean basin, and in eastern and northern Africa, at all of which points it merges into the nose of the hyper-phylo-morph.

The hyper-phylo-morph nose is long, high and narrow, with high root, bridge and tip, the nostrils flare but little and open almost directly downward. The nostrils may even open somewhat backward in the exaggerated forms, as in the Jew, for instance. The nose appears prominent and may seem larger than it really is, inasmuch as the jaws are not prognathous, and the brows and glabella do not overhang the nose; the forehead and chin may even recede leaving the nose projecting from the middle of the face. The nose may be retroussé, straight, sinuous, or aquiline. The retroussé, seen chiefly among women, is the underdeveloped, whereas the aquiline, seen chiefly among men, is the exaggerated form of the hyper-phylo-morph nose. Associated with this form of nose is the long, narrow face, and the long, high, narrow head. The distance from the external auditory meatus to the tip of the nose is greater in this form than in either of the others, and this projection of the nose to a pointed tip in association with the high, narrow forehead and pointed chin give the characteristic appearance called by the Australians in derision, "the hatchet-faced Englishman."

The most representative types of the hyper-phylo-morph nose in its primary form are found in northern Europe, Great Britain, and America, among the tall blonde Nordics, and this form of nose has been modified around the Mediterranean where it is extremely fine and thin. Its most exaggerated forms are to be seen among the Jews, Arabs, and Gypsies. It is found more or less modified in Asia and Africa along the course of four streams of infiltration. The most intense forms (the most perfect) are in southern Asia and northern Africa, the least intense in northern Asia and eastern Africa. The American Indians present a hyper-phylo-morph nose of an intermediate form between that of the extreme meso-phylo-morph and the primary hyper-phylo-morph. The characteristic hyper-phylo-morph nose dwindles in purity and frequency through southern Asia and northward through the hearts of the large islands of the Pacific among the inland tribes, except among the Tasmanians, Australians and Melanesians, to the inland tribes of the Philippine Islands, and eastward into Polynesia; through northern Asia into China and Japan, where in the latter place the nose is similar to that of the Mediterranean peoples; through northern Africa into the Soudan to the Guinea coast, and through eastern Africa to the Congo and along the south and east coasts up to the Guinea coast and the Congo again. The peoples who have this form of nose in greatest purity may be enumerated as follows: Danes and Scandinavians, North Germans, British, America whites in the United States and Canada, Spanish, Portuguese, some southern French and Italians, Greeks, Turks, Arabs, Jews and Gypsies. Those peoples among whom modified, yet fairly typical, forms are frequent are: East Indians, Iranians and Turanians, North and East Africans, Europeans other than those previously mentioned, Chinese, Japanese and Thibetans, Polynesians and Micronesians, and the inland tribes of the great islands of the Pacific, Java, Sumatra, Borneo, Celebes, and the Philippines.

The three forms of the nose may appear pure among any people, and in differentiating the three forms in any locality I use the terms hypo-onto-morph, meso-onto-morph and hyper-onto-morph because in every individual it may not be clear that the form of the nose is due to evolution—it may be developmental. The -onto-morph noses are not so strikingly different as the -phylo-morph forms, but in any case the hypo-onto-morph resembles the hypo-phylo-morph, the meso-onto-morph resembles the meso-phylo-morph, and the hyper-onto-morph resembles the hyper-phylo-morph.

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February 1913

THE NOSE OF THE JEW AND THE QUADRATUS LABII SUPERIORIS MUSCLE

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The peculiar position of the Jew for centuries may account for the origin of the Jewish nose. The shape of the nose depends upon inherent and extraneous influences. The latter do not concern us at present. Of the inherent influences, alterations in the bones of the head and face cause changes in the shape of the nose; increased vascularization of the nasal mucous membrane and the erectile tissues of the nose, as in continued excessive sexual indulgence, may alter the shape of the nose; and the muscles attached to the nose may change its form.

The quadratus labii superioris muscle has four parts, all of which center around the alae of the nose and the base of the upper lip, and from there they radiate towards the eyes in the shape of an imperfect fan. The two extremities of the fan are attached, the one at the root of the nose, the other to the ventral surface of the malar bone. The part of the quadratus muscle attached to the nose is called the angular head, which has two slips, one rising from the nasal bone and inserting into the cartilage and tissues about the ala of the nose; the other arising from the upper part of the nasal process of the maxila near the inner canthus of the eye and inserting into the skin and fascia at the base of the upper lip midway between the center and the side of the mouth. The angular head has been called the 'levator labii superioris et alaeque nasi muscle,' a term that expresses its action. The muscle slips pull the ala of the nose upward and backward, depress the extremity of the nose, and help to elevate the upper lip and deepen the naso-labial groove. The two remaining portions of the quadratus muscle are called the levator labii superioris and the zygomaticus minor, which form the infraorbital and zygomatic heads, respectively. They rise from the maxilla and malar bone beneath the orbicular muscle and are inserted into the skin and fleshy part of the upper lip near the corner of the mouth. They pull the upper lip upward and backward and deepen the naso-labial groove. Deepening of this groove gives an expression of sadness, which is intensified by sorrow or grief. Assisted by the great zygomatic muscle, and the caninus, the quadratus draws the tissues covering the chin upward and backward, pulls the corner of the mouth in the same direction and deepens the naso-labial groove. This sharpens the chin and makes it appear to tilt upwards in the form of a beak. The depression of the point of the nose tilts this member downward and gives it the appearance of an inverted beak. The mouth is at the same time drawn back, and the double beak becomes more emphatic.

The quadratus muscle is said to produce expressions of the face that indicate a great variety of emotions, all of which may be grouped as related to indignation. It is essentially the muscle of disgust, contempt, and disdain, which lead to scorn, acknowledging guilt. Discontent follows, with a snarl, sneer, and defiance; after which comes bitterness, and a menacing attitude, with pride. Indignation, anger, rage, and hatred rapidly succeed each other. This complex of emotions may be superseded by sadness, grief, or sorrow. That one small muscle group can express so many emotions is almost inconceivable, but upon intimate analysis the nineteen words used to enumerate the emotions expressed by the quadratus muscles are related, or proceed the one from the other in natural sequence.

The expression of the Jew is that which would result from very strong contraction of the quadratus muscle. The nose is depressed, and this is so marked that often an obtuse angle is made at the junction of the cartilage and nasal bones, which leaves the cartilage slanting very little and at times vertical. The nose of the Jew is large, and the depression of the tip increases the prominence of the bridge and adds to its apparent size. The ala looks pulled upward and backward, a furrow is seen around the ala, and the naso-labial groove is deep. The upper lip and the corner of the mouth appear pulled upward and backward, and the tissues of the chin are drawn, giving the beaked look. This characteristic is not well marked on all Jews, but is more emphatic on some than on others; it is also to be seen on those who are not Jews, but it is more pronounced on Jews than on other peoples, and that it is a Jewish feature cannot be doubted. Having become a recognizable characteristic, it was used in sexual selection. Those who showed it most strongly would be selected in marriage by the most orthodox, and would transmit a natural endowment to their offspring. Those who gave less evidence of it might marry outside of the race. In this way the feature became fixed, and it is as much an inheritance as any other characteristic. The peculiar position of the Jew for centuries may account for the origin of the Jewish nose.

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NOTES ON THE HAIRY MEN OF THE PHILIPPINE ISLANDS AND ELSEWHERE

By ROBERT BENNETT BEAN

THE people of the Philippine archipelago are for the greater part glabrous except for the hair of the head. The Negritos frequently have short, stubby beards, and a scant amount of hair on the face is not unusual with the other peoples. The hairiest men of the islands are found in the heart of Luzon and Mindanao, especially in the former. These are the largest islands of the group and have retained aboriginal populations longer than any of the other islands. The center of the group of hairy men is in the Ilongot Igorot country, in the eastern southern central part of northern Luzon. They border the purest Negritos of the archipelago on the east, the Igorots on the north and west, and on the south the Filipinos, who have penetrated the province of Nueva Viscaya.

The inhabitants of the Philippines may be grouped roughly into three divisions: the coast people or Littoral Filipinos, the people of the interior or Inland Filipinos, and the Moros or Mohammedans of the Sulu archipelago and Mindanao. The largest portion of the Inland peoples is the Igorot, occupying the central mountainous part of northern Luzon. The Ilongot Igorots form the southeastern division of them, and it is among the Ilongots that the greater number of hairy men have been seen, although their northern neighbors, the Ifugao Igorots, have also a few hairy men. The Subanuns of central Mindanao have likewise a few bearded men.

It is, however, the Ilongot Igorot hairy men that chiefly concern us, and an attempt will be made to illustrate the similarity that exists between these hairy men and the Ainos of Japan, the hairy men of Australia, the Todas of southern India, and the Europeans.

When I was in the Philippines (1907–1910) I was impressed with the occurrence of hairy men resembling Europeans among the

Ilongots and Subanuns, and procured all the pictures I could find in the Bureau of Science in Manila (see pls. XXI–XXX, figs. 78 to 85). These seemed to be inadequate, but recently Worcester has published pictures of hairy men, not only of the Ilongots, but of the Ifugaos, their northern neighbors (see figs. 86–90).

A cursory inspection and comparison of the four groups of hairy men from the Philippines, Japan, Australia, and India will emphasize similarities and at the same time will illustrate differences (see pls. XXI–XXIX, figs. 78–107). The men all have beards and mustaches, and some have side-whiskers. In some the hair is plentiful on the face, in others it is scant. Heavy beards with mustaches and whiskers exist in each group (see figs. 78, 79, 93, 94, 95), and no doubt scant beard and mustache without side-whiskers, as represented for the Filipinos and Australians, may be found in all the groups, although none is shown among the Todas and Ainos. A similarity of the features of the face may also be seen in each group, especially if the hairiest individuals are selected. Compare the Ilongot of figure 78, the Australian of figure 79, the Aino of figure 99, and the Toda of figure 93. With these may also be compared the Cingalese man of figure 106, and the Korean of figure 107. There is something about all these men that any competent observer will at once assign to the European (Caucasian or white) people. What is it that gives the appearance of similarity?

In the first place, the beard, mustache, and whiskers give a somewhat uniform appearance to the face below the nose, hiding the lips and chin and obscuring the mouth. In the second place, the nose is straight-lined and the nostrils open downward. In the third place, the upper eyelid has a line immediately above it made by the turning in of the upper lid under the fold above. This distinguishes the European from the Mongolian eye. In the latter the lid disappears beneath the fold above, only the lashes project, and the inner end of the upper lid is attached below the inner end of the lower lid, which passes under it. The lids are occluded evenly in the European, and the line of occlusion is more or less straight and horizontal from the inner canthus to the outer, whereas in the Mongolian eye the upper lid overlaps the lower lid

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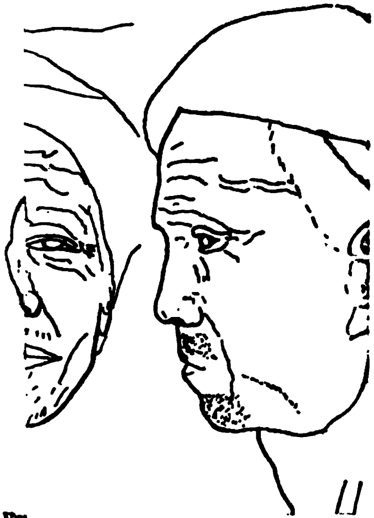

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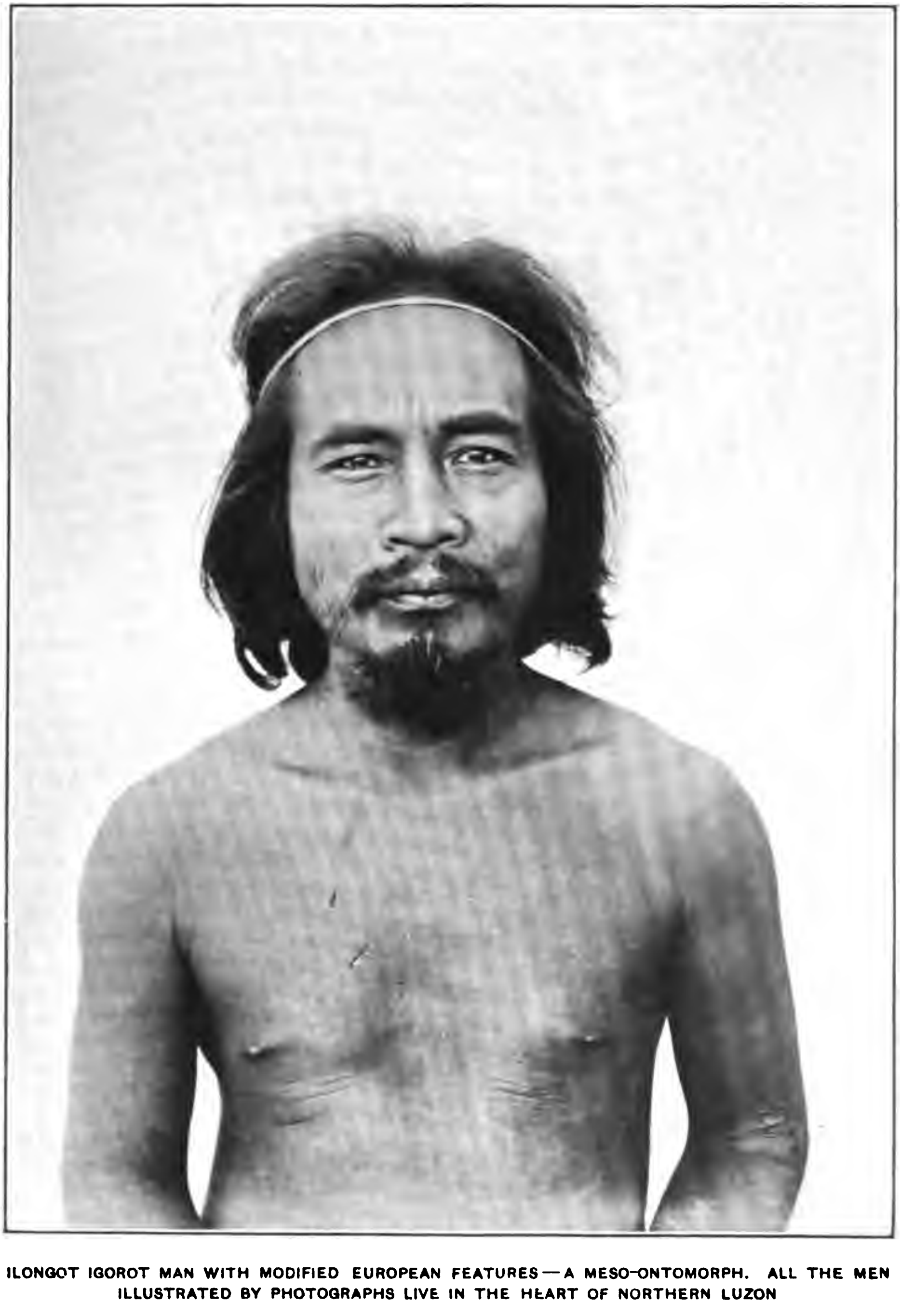
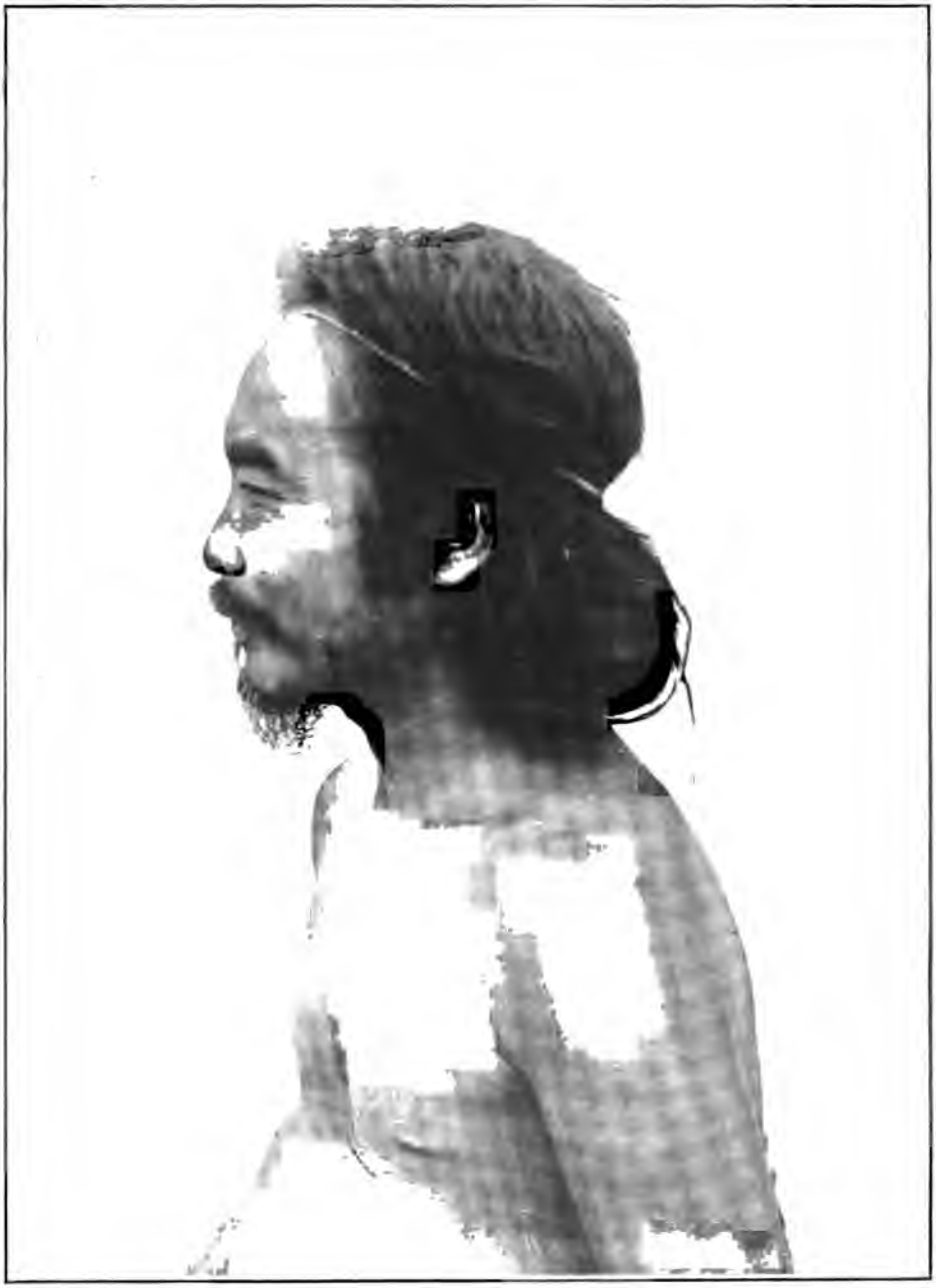


ILONGOT IGOROT MAN WITH MODIFIED EUROPEAN FEATURES — A MESO-ONTOMORPH. ALL THE MEN ILLUSTRATED BY PHOTOGRAPHS LIVE IN THE HEART OF NORTHERN LUZON



ILONGOT IGOROT MAN (PROFILE OF PLATE XXI) at the inner canthus, where the line of occlusion is not continuous, and the upper lid forms a bow with a dip at the nasal end and the convexity upward. In the fourth place the hair of all the individuals is straight or nearly so.

In spite of the similarity of the six men under consideration, there are noticeable differences especially in the characteristics of the nose. The Ilongot (fig. 78) has a short nose, and so has the Australian; whereas the noses of the Toda, Cingalese, and Korean are long and relatively narrow, and that of the Aino is somewhat intermediate. The faces of the Korean, Cingalese, and Toda are also longer and narrower than the faces of the others, although in this appearances may be deceptive, because of the beard.

From these examples of hairy men who resemble the European, we may turn to others, and in each of the four groups the remaining individuals resemble the surrounding peoples. The Ilongot of figure 80 resembles the Malays, with scant beard and mustache, and no whiskers; stiff, straight coarse hair; almond-shaped eyes, wide apart; round face and head; flat nose with depressed root and bridge, and prominent cheek-bones. The Ilongot of figure 82 resembles the Malay and Negrito, and the Ilongot of figure 83 the Negrito. The attention is at once fixed by the negroid features, curly hair, large mouth, thick lips, and short, flat, stubby nose. The Igorots of figures 86 and 86*a* resemble the Ifugaos, who are long-faced men, and the Igorots of figures 87 to 90 resemble the Ilongots, who have short faces and noses. The Australians of figures 100 to 103 approach nearer and nearer the Negro type, from the man in figure 100, who is semi-European in appearance, to the man in figure 103, who is very nearly like the Negro. The Ainos of figures 95 to 98, also figure 104, approach the lower-class Japanese and the Malay. The Todas of figure 94 approach this form in a slight degree, but there, especially in figures 91 and 92, the European features dominate. The Subanuns of figures 81, 84, and 85 change from the European to the Arab, due to the admixture of the Moro or Mahommedan, who came from Arabia through Sumatra to the Sulu archipelago and Mindanao, as the immediate precursor of the Spaniard in the Philippines. This and previous studies of the Filipinos have convinced me that the Malays are mixtures of many peoples, and that the Malay as an entity is a myth. In the Philippines today are to be found the following components: First the Negritos, then the hairy men, after which the "Proto-Malays," who have a large proportion of tall, long-headed, long-faced, long-nosed people (Indo-European) mixed with the Mongolians who came from southern Asia and drifted through the Pacific islands. They constitute the greater portion of the inland tribes of the Philippines. Later came the "Neo-Malays," some of the same stock as the "Proto-Malays," with a greater proportion of the Negrito, hairy men, and Mongolian mixture, making them smaller in stature, more broad-headed, and with broad face and nose. These enter largely into the littoral population of the Philippines today. Wandering peoples from India settled here and there from time to time, and the Moro came to the southern islands, Sulu and Mindanao, where their spread was stopped by the Spaniards. Recent introductions of European and American whites and American negroes add to the polyglot, making the Philippines one of the richest fields in the world for the future anthropologist. The final work has not been done, the final word has not been said. Only the surface has been scratched.

Returning then to our subject, it would seem that a hairy people of whom the Todas are a remnant, and who resemble the Europeans, occupied the mainland of southern Asia and the adjacent islands at some remote time, and there is evidence of contact with the Negro in Australia and the Negrito (little negro in reality) in the Philippines. This contact has altered both peoples, more especially the Australians and Filipinos, where the hairy men have practically disappeared; to a less extent the Todas and Ainos, of whom the hairy people form the greater part. Yet even today there are a few hairy men in Australia and the Philippines who resemble Europeans, although the greater part of the native population of these two places belongs to other stocks.

Race apparently has not been the only influence at work, because the Ainos, who are presumably the purest of the four hairy groups, are most different from the Todas, who are supposed to be more like

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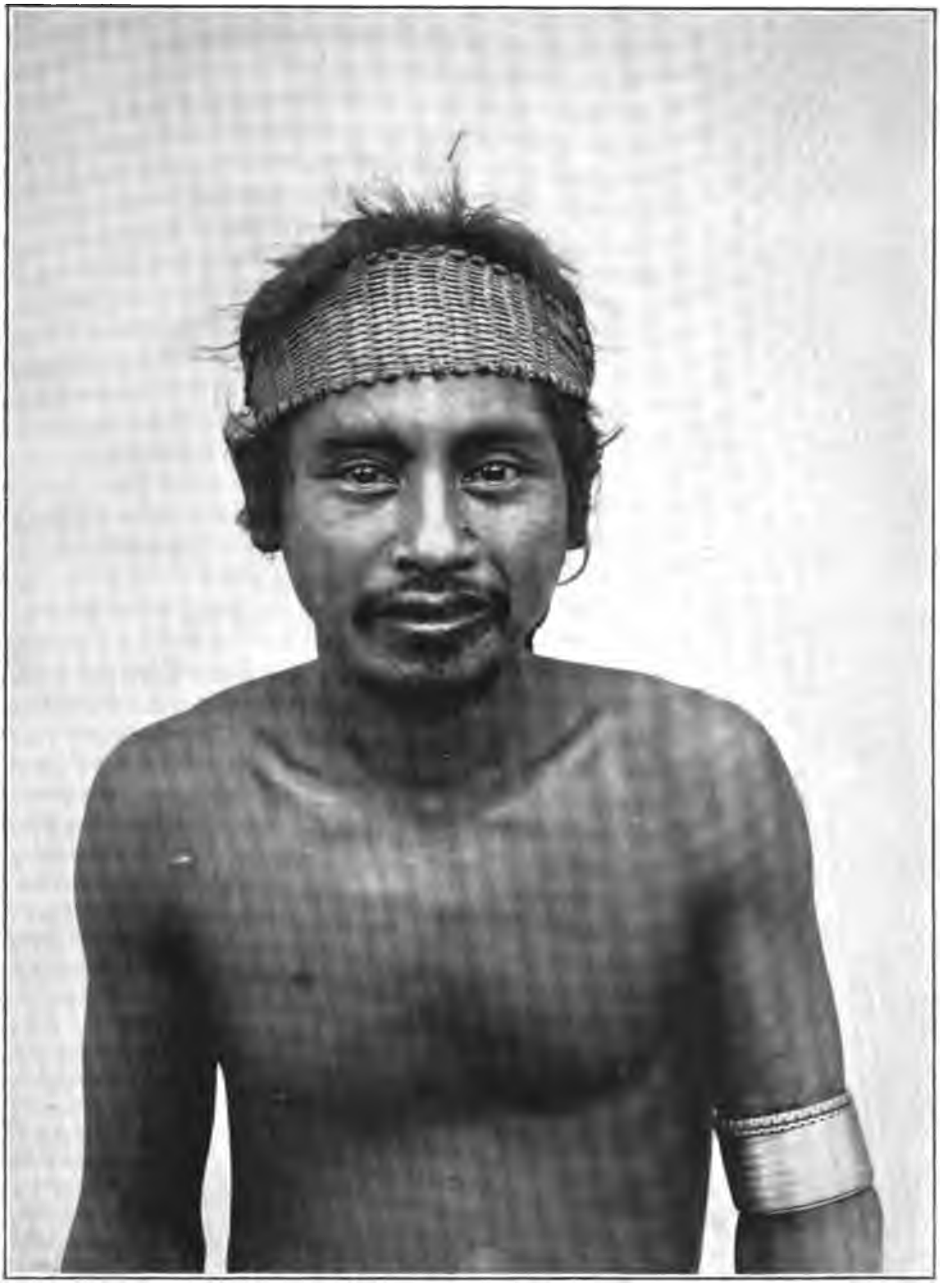
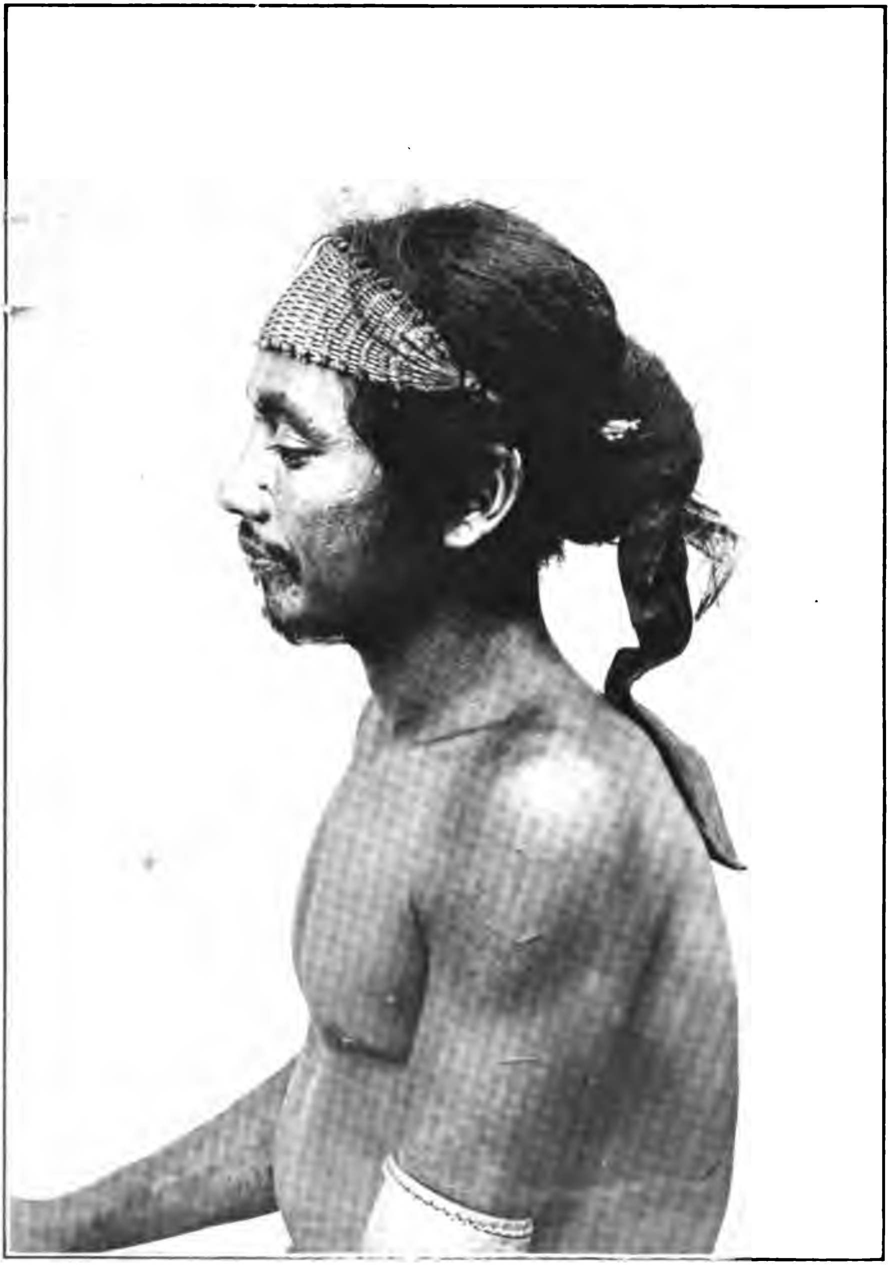


ILONGOT IGOROT MAN WITH MODIFIED EUROPEAN FEATURES—A MESO-ONTOMORPH



ILONGOT IGOROT MAN WITH MODIFIED EUROPEAN FEATURES (PROFILE OF PLATE XXIII) the precursors of all the groups. The Todas, however, may have been altered by mixture with the tall long-heads, Indo-European from the northwest, and the Ainos may be more like the aboriginal form. The nose of the Aino, of the hairy Igorot, and of the hairy Australian is more or less infantile in form, and resembles that of all the Pacific peoples, except recent intruders. Without known contact, the peoples of the whole region have this infantile form, which is reason for believing that environment and selection as well as heredity and variation have had their share in molding the form of these peoples. The conditions of life at present found in all four groups of hairy men may account in part for their present physical form. Some of the contributing causes have been a diet of fish and rice, a plethora of animal parasites intestinal and cuticular, faulty nutrition, habits of indolence, and climatic conditions, any one or all of which would tend to a retention of the infantile physical form.[1]

Measurements of the hairy men of the Philippines have not been made, and it would be of great interest to know their face, head, and body form. Anutschin[2] and Koganei[3] describe the Ainos as of medium stature, although there is a small group of tall stature. The forehead is high and broad, the nose is broad but not flat, and the lips are thick. The face index is intermediate, and the cephalic index is subdolichocephalic to mesocephalic (77.9 to 78.6). Lefèvre and Collignon[4] give records of the color of hair and eyes of 42 men and 48 women in whom the eyes are "foncès" and the hair brown or black. Von Baelz[5] relates the Riu-Kiu islanders to the Ainos by reason of their hairiness and resemblance to Europeans, and gives them a stature of 157–9 cm. and a cephalic index of 78 to 81. The measurements of these authors on the living are confirmed by von Török's[1] measurements of the skeleton of the Aino. Twenty skulls give the following indices: *Cephalic:* Dolicho, 57.8%; Meso, 42.11%; Brachy, 0.0%. *Facial:* Leptorrhine, 11.11 %; Mesorrhine, 50%; Platyrrhine, 38.88%.

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[1] Worcester, Dean C., Head-hunters of northern Luzon, *National Geographic Magazine*, Sept., 1912.

[2] Anutschin, D. N., Materialen zur Anthropologie ostasiens. I. Der Stamm der Ainos, *Beitr. z. XX Bd. d. Nachrichten d. k. Gesellsch. d. Liebhaber d. Naturforschung, Anthropologie u. Ethnologie*, Moskau, 1876, pp. 79–203.

[3] Koganeī, Kurze Mittheilung u. Untersuchungen an lebenden Aino, *Arch. f. Anth.*, XXIV, 1–39.

[4] Lefèvre, H., et Collignon, La couleur des yeux et des cheveux chez les Ainos, *Rev. d'anthropologie*, 1889, pp. 129–141.

[5] von Baelz, E., Die Riu-Kiu Insulaner, die Aino, und andere kaukasierähnliche Reste in Ostasien, *Sitzungsberichte d. Anthr. Gesellsch. in Wien*, 1911–12, pp. 133–137.

Forty-three more skulls are classified as 13 European, 25 intermediate, and 5 Mongolian.

Sir William Turner[2] compared 17 skulls of Dravidians and 19 of Kolarians from southern India with many Australian skulls and concluded that the Kolarians and Dravidians are of the same stock, something that Risley had demonstrated by measurements of 6,000 people. The people of southern India resemble the Australians in two significant characteristics—they are both dolichocephalic and platyrrhine. In minor traits, such as the projecting glabella, depressed nasion, prognathic upper jaw, elongated palate, and coarse, large teeth, as well as roof-shaped crania, the Australians are more pronounced. The similarity of Dravidians, Kolarians, and Todas of southern India to the European is so well marked that no one doubts the affinity. The southern Indians and the Ainos have a closer resemblance to the European than is borne by the Filipinos and Australians, and the two former also include a larger body of hairy men than the two latter. This would seem to indicate that either a larger number of the hairy men located originally in Japan and India than in the Philippines and Australia, or they are more recent arrivals in the former places, or else local conditions enabled them to survive in the former rather than in the latter places. All three suggestions may apply.

Further studies of plates XXI–XXX and figures 78–107 from the standpoint of my classification of the ear, nose, and face, may

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[1] Török, Aurel, Ueber den Yézoer Ainoschädel aus der ostasiatischen Reise des Herrn Grafen Béla Szechenyi und über den Sachaliner Ainoschädel des königlich-zoologischen und anthropologisch-ethnologischen Museums zu Dresden. Ein Beitrag zur reform der Craniologie, *Arch. f. Anthr.*, Band XXIII, viii, pp. 249–345; Band XXIV, pp. 277–338; ditto, pp. 479–576; Band XXVI, pp. 95–144, 247–315, and 561–690, and Anhang, pp. 1–108.

[2] Turner, *Sir* William, Contributions to the craniology of the peoples of India. Part II, The Aborigines of Chuta Magpur, of the central provinces and the people of Orissa, *Proceedings of the Royal Society of Edinburgh*, Session 1899–1900, pp. 161–162.

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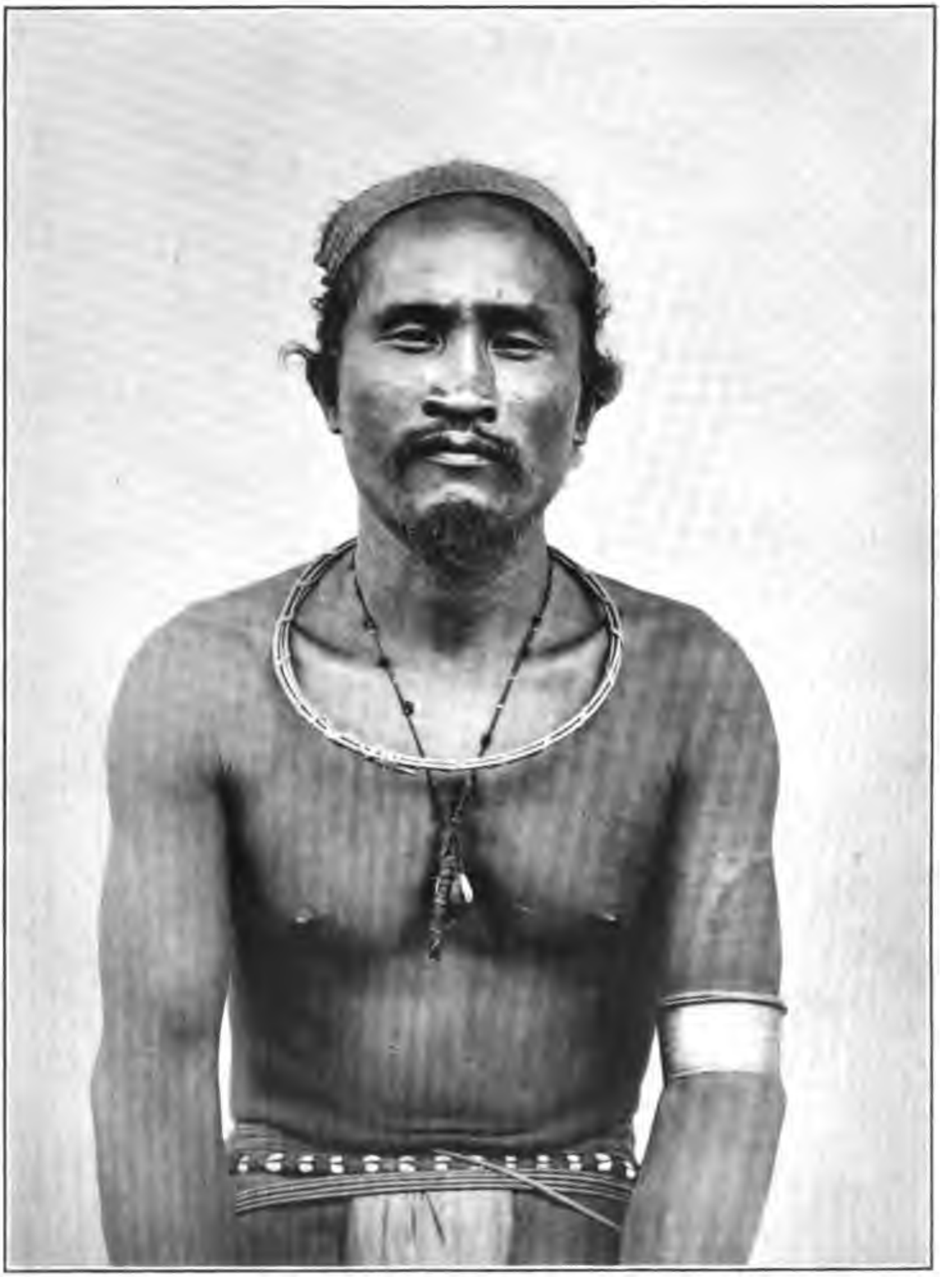
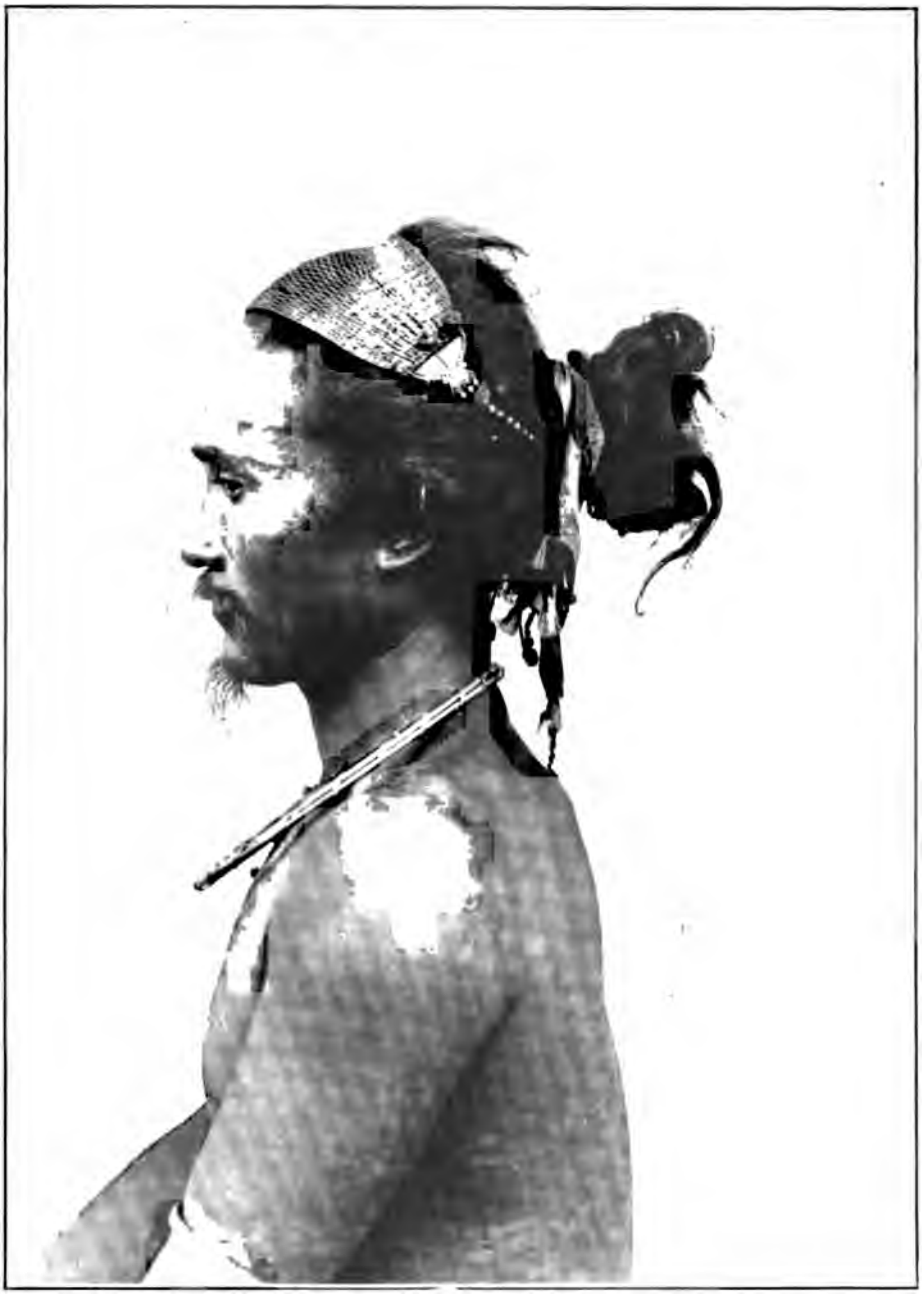


ILONGOT IGOROT MAN WITH MODIFIED EUROPEAN FEATURES—A MESO-ONTOMORPH APPROACHING HYPER-ONTOMORPH



ILONGOT IGOROT MAN (PROFILE OF PLATE XXV) not be without illumination. Outlines from pictures of three citizens of the United States belonging to the European stock, chosen at random from among several thousand, are given in figures 108–110 to facilitate the conception of three forms that I believe to be fundamental throughout the world.

The hypo-ontomorph of figure 108 is more or less infantile in appearance. The face is round or oval, the nose short and broad, the eyes far apart, the ear bowl-shaped or trumpetlike.

The hyper-ontomorph of figure 109 is sharply contrasted with the hypo-ontomorph. The face is long with pointed chin, the nose is long and thin, the eyes close together, and the ears have the central part, anthelix, tragus, and antitragus everted, and the periphery, helix, rolled back.

The meso-ontomorph of figure 110 has a large face with straight sides, pyramidal nose, big mouth, and large, square, flat ears.

The three original forms from which these are supposed to have evolved are called respectively the hypo-phylomorph, the hyper-phylomorph, and the meso-phylomorph.

The hypo-phylomorph is the true infantile form with the adult size, and is found most frequently and distinctly in the large islands of the Pacific ocean associated with what is called the Malay peoples (see fig. 83).

The hyper-phylomorph is represented by the Nordics of northern Europe, and the Cro-Magnon people of southern Europe, as well as by such people as the Igorots of northern Luzon. They are tall, with long heads, faces, and noses. The face is pentagonoid and not like the triangular face of the derived hyper-ontomorph. The nose is large as well as long, and not so fine and thin as that of the hyper-ontomorph (see figs. 99, 106, 107).

The meso-phylomorph is represented among the Australian and Negroid peoples generally and elsewhere, although the true negro is not the pure meso-phylomorph, but a modified form. The meso-phylomorph has a large face, usually ellipsoid, a nose that is straight in outline and pyramidal in shape, with ears that are large and more flattened than those of the meso-ontomorph (see fig. 101).

The six groups may be placed in serial order and those nearest will resemble each other more than those farther away.

1. Hypo-phylomorph.	4. Meso-ontomorph.
2. Hypo-ontomorph.	5. Hyper-phylomorph.
3. Meso-phylomorph.	6. Hyper-ontomorph.

This series represents six forms that merge into each other in any group of people, and it also represents the six forms through which each individual develops, unless the growth or development of the individual ceases before the stage of the hyper-ontomorph is reached.

The phylogeny is conceived to be something like this: The phylomorphs represent three conditions reached by three different groups of segregated peoples under different environment. The ontomorphs represent stages of individual development, or forms produced by the crossing of the three phylomorphs where they come into contact, and in any group of peoples today the ontomorphs differ in degree of development from those of any other group. For instance, the ontomorphs among the Filipinos would be less developed than the ontomorphs among the Spaniards.

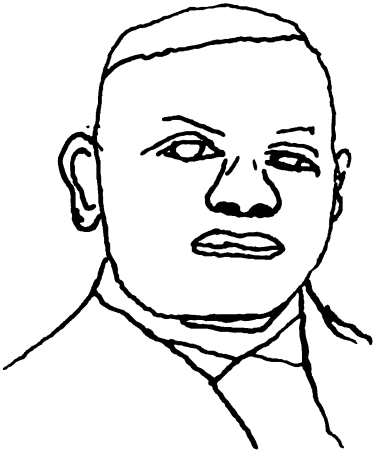


FIG. 108.—European hypo-ontomorph.

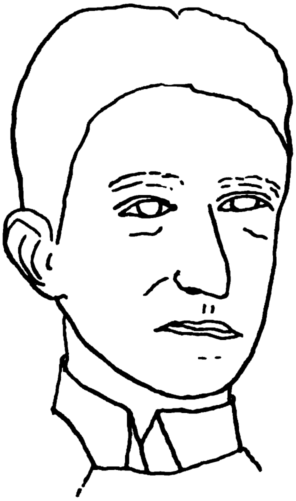


FIG. 109.—European hyper-ontomorph.

It may be difficult for anyone without considerable experience to differentiate between the ontomorphs and the phylomorphs, but there can be little difficulty, even for the inexperienced, in differentiating between the hypo, meso, and hyper forms, especially if one bears in mind the faces represented in figures 108–110.

The hypo-phylomorph is well represented in figure 83, disregarding the hairy parts. The nose is buttonlike, with broad, flat bridge, depressed root, with the concavity forward. The nostrils flare and the tip of the nose is tilted upward so that the nostrils open forward. The eyes are wide apart and the lids are almost closed. The upper lids are so puffy, as if infiltrated and swollen, that they not only nearly close the eyes, but the upper lid retreats beneath the fold, leaving only the lashes protruding. The upper lid is attached to the face below the attachment of the lower lid at the inner canthus. The eyes and nose are those of the infant, and the Mongolian fold is pronounced. The ear is trumpet or bowl shaped, although the upper part of the ear is covered by hair and cannot be seen.

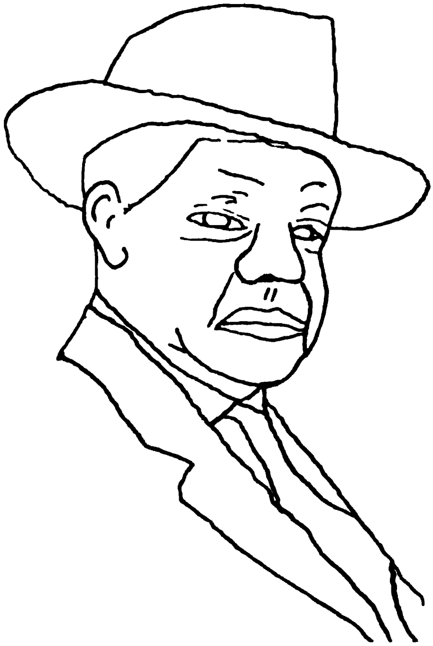


FIG. 110.—European meso-ontomorph to meso-phylomorph.

The meso-phylomorph is fairly well represented in figures 100–103 of Australian men. The brow ridges and glabella are large, giving a depressed root to the nose and a formidable expression to the face. The nose is pyramidal in shape and large in all dimensions, with straight lines along the bridge, sides, and base. The mouth is large and the lips thick, with considerable surface of mucous membrane exposed. The ear is semi bowl shaped, but the concha is not so deep as in the hypo-phylomorph.

The hyper-phylomorph is shown poorly in figures 99, 106, and 107, an Aino, a Cingalese, and a Korean. There the nose is high, long, and moderately narrow, but not the long, thin, high, narrow nose of the hyper-ontomorph. Other figures, as 91, 92, and 93, show the transition to the hyper-ontomorph, as figure 109 represents the ultimate form of the latter.

The analysis of the number of each form as found among the thirty-eight men here under consideration in the four groups may not be without interest.

Analysis of the Forms of Hairy Men

Hypo-phylomorph	Hypo-ontomorph	Meso-phylomorph	Meso-ontomorph	Hyper-phylomorph	Hyper-ontomorph	Total
4	3	13	8	9	1 (?)	38
Hypo		Meso		Hyper		
7		21		10		
Phylomorphs			Ontomorphs			
26			12			

It may be said that the earlier, more generalized or less developed forms of men (phylomorphs, 26) are greater in number than the later forms (ontomorphs, 12). The meso group is also larger (21) than either the hyper (10), or the hypo (7). The inference may be that the hairy men of the four groups, Ainos, Igorots, Australians, and Todas, are remnants of a stock whose form was that of the meso-phylomorph, that spread over a considerable part of the Eurasian continent and the great islands adjacent at some remote period of time.

There can be no doubt that the four groups of hairy men are related, as demonstrated by measurements of the living and of the skeleton, as well as through the present study of their physiognomy. There can be little doubt that the four groups of hairy men are related to the European (Caucasian or white) peoples. The process of evolution has lengthened the stature, face, and nose of the meso-morph and produced the hyper-morph; and shortened the stature, face, and nose and produced the hypo-morph.

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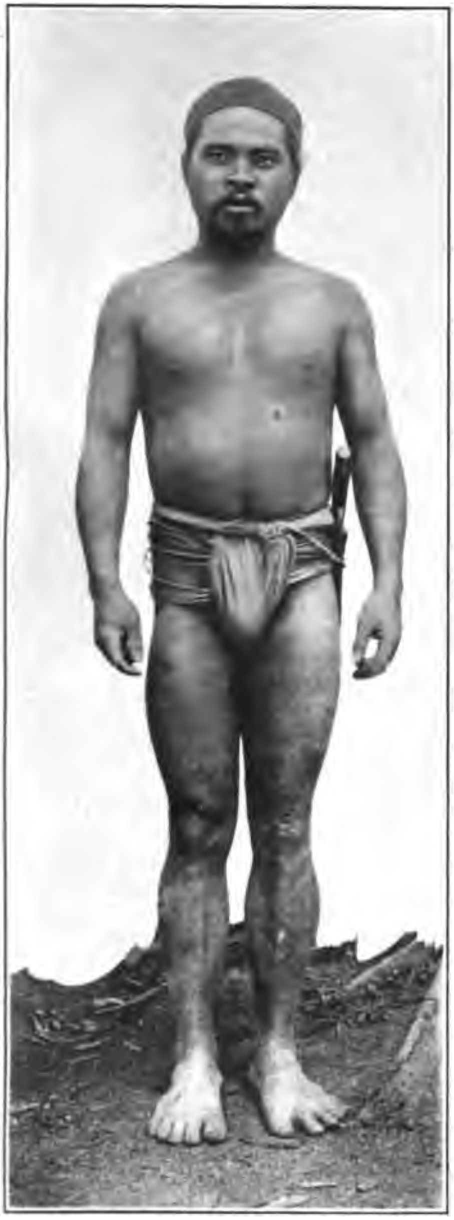
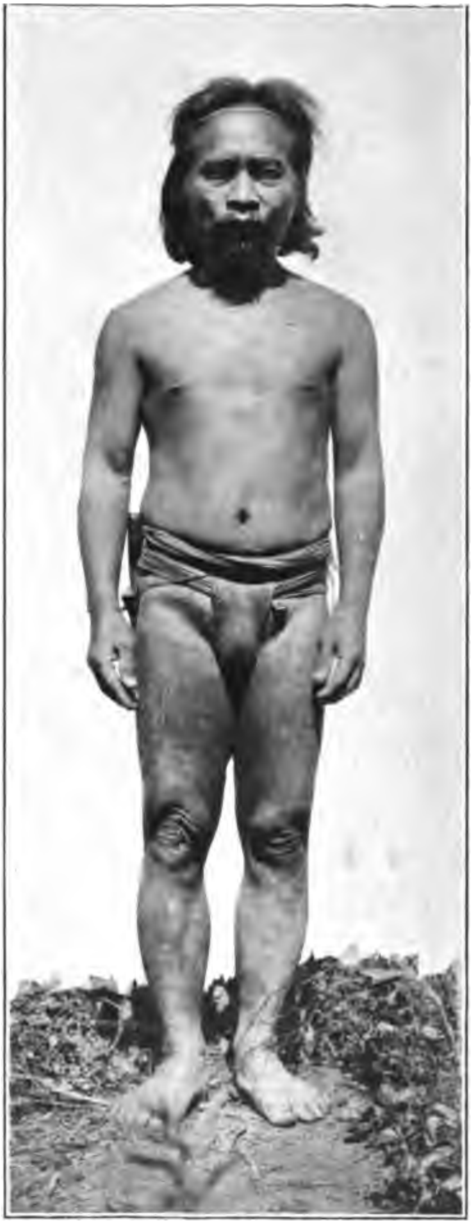
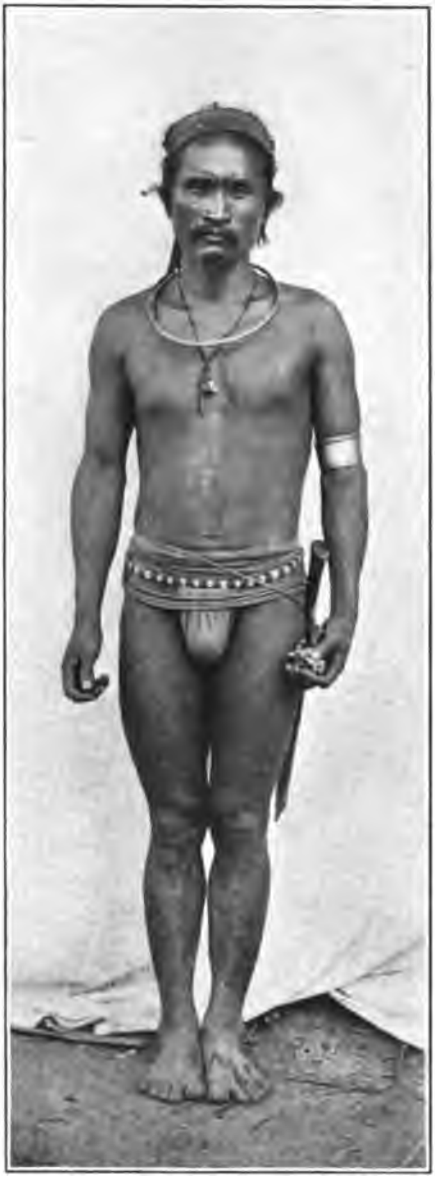


a. ILONGOT IGOROT MAN WITH MODIFIED EUROPEAN FEATURES RESEMBLING THE JAPANESE — A HYPO-ONTOMORPH

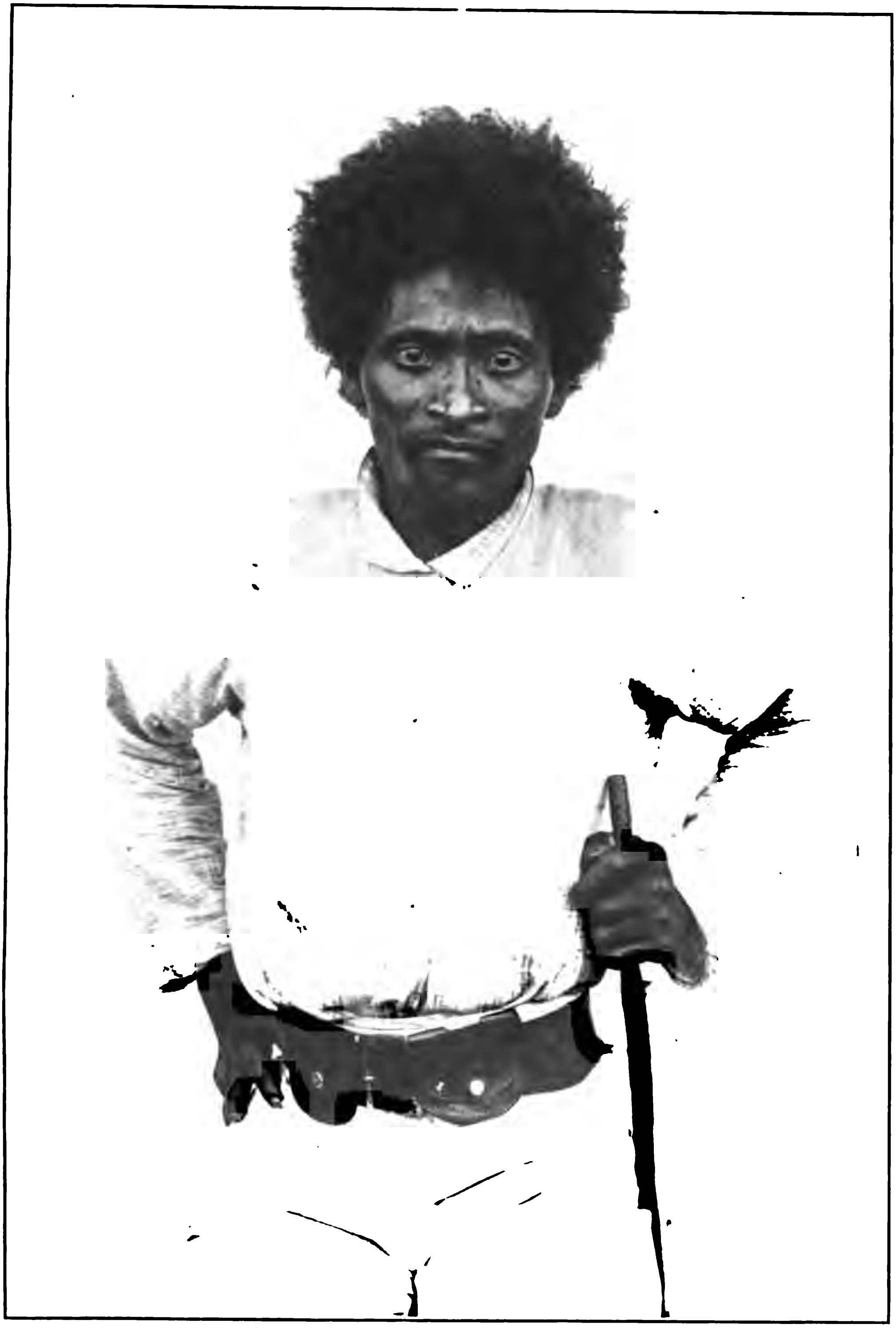


b. ILONGOT IGOROT MAN (THE SAME AS PLATES XXI AND XXII)

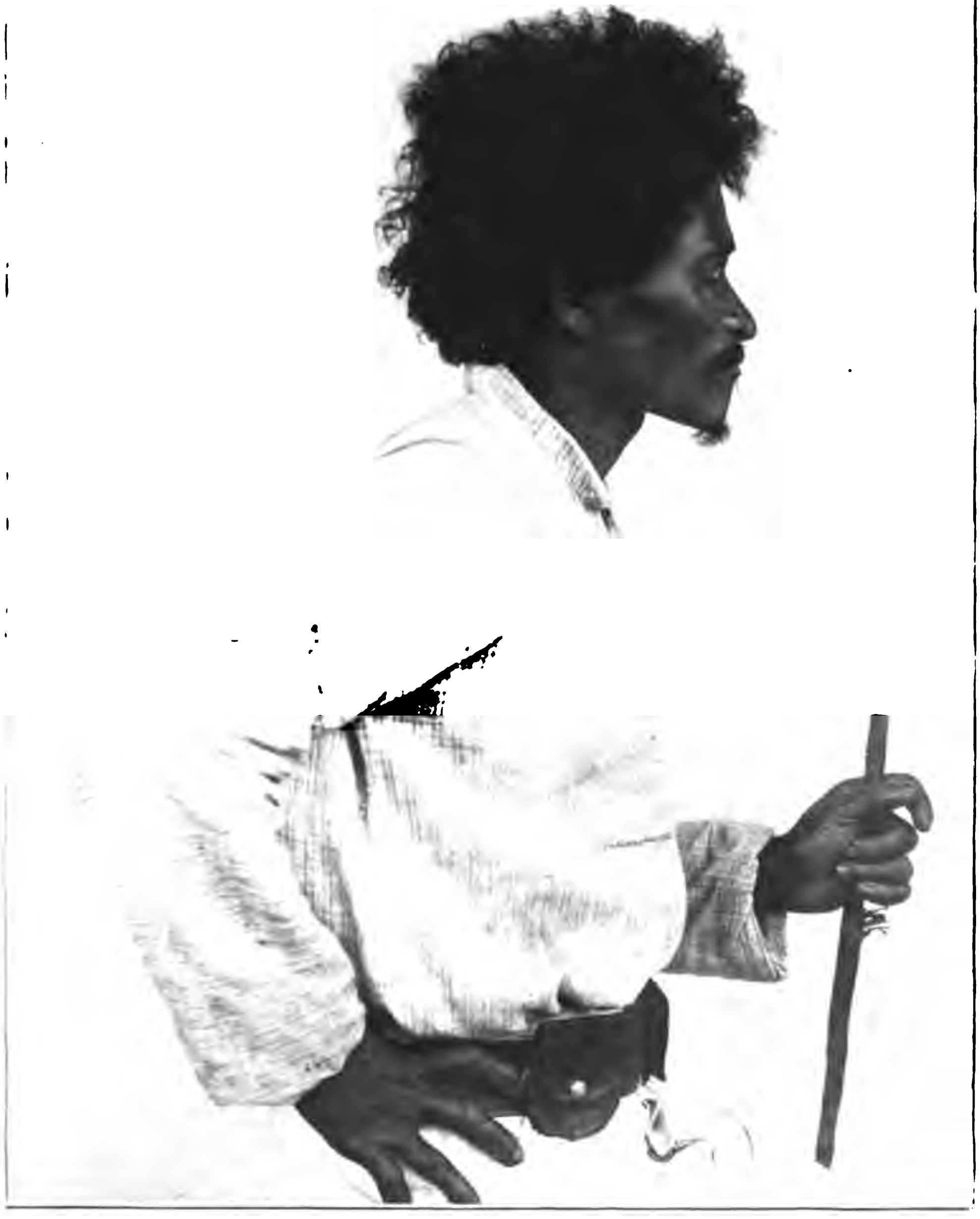


ILONGOT IGOROT MAN

(THE SAME AS PLATES XXV AND XXVI)



NEGRITO CHIEF, PAGATOLON, OF NORTHERN LUZON, WITH MODIFIED EUROPEAN FEATURES THIS MAN HAS TWO ALBINO CHILDREN. MODIFIED HYPER-ONTOMORPH



NEGRITO CHIEF, PAGATOLON (PROFILE OF PLATE XXIX)

Read Hypo-morph for Primitiv
" Meso-morph " Austral
" Hyper-morph " Iberia

TYPES AMONG THE INLAND TRIBES OF LUZON AND MINDANAO

By Robert Bennett Bean

(*From the Anatomical Laboratory, Philippine Medical School, Manila, P. I.*)

Nine plates and 1 map

Luzon and Mindanao are the largest of the Philippine Islands. Therefore, one would suppose that the tribes in the interior of the two islands have been influenced less than those on the coast by recent mixtures with the Malay and European, and the types among those tribes would represent the primary elements of the Filipinos. Having this supposition in mind, I have attempted to select representative individuals from the best known groups of the interior of the two islands to serve as a basis for a fuller study of the inland tribes, which is to be undertaken subsequently.

The tribes selected for this study are the most numerous of all in the Islands and include the Bontoc Igorots, Benguet Igorots, Ifugaos, and Kalingas of Luzon; and the Moros, Bagobos, and Subanuns of Mindanao. The photographs were selected from the collections of Mr. Dean C. Worcester and of the Bureau of Science.

THE BONTOC IGOROTS

The Bontoc Igorots are so well known and have been so fully treated by others that it is not necessary to do more than mention them, but it is of interest to note the presence of the Iberian and Primitive types here as elsewhere among the inland tribes. In Plate I, figs. 1, 2, and 5, may be seen two Iberian men of Bontoc. The evident Iberian characteristics are the long narrow face, the long narrow nose, the pointed chin, and the Iberian ear type A—recognized by absence of lobule, eversion of concha, and rolling out of helix at the lower part. These men have long narrow heads which cannot be determined exactly from the photographs because of the hair. The Primitive type of Bontoc Igorot is represented in Plate I, figs. 3, 6, and 7. The young woman has the broad flat face, short broad nose with depressed bridge and flaring nostrils that open somewhat downward, and the bowl-shaped ear with much rolled-in helix; the man has a somewhat longer face, straight nose with nostrils opening downward, and modified Alpine ear that has qualities of the Iberian type A in the absence of lobule and somewhat everted concha, and of the Primitive in the rolled-in helix, denoting a mixed type. In a former study of the Benguet, Lepanto, and Bontoc Igorots three types were selected and entitled M, A, and N, which may now be designated as the Iberian, Australoid, and Primitive, respectively. The three types may also be segregated by the examination of photographs using descriptions as an aid in their interpretation as in the previous study.

THE BENGUET IGOROTS

Two characteristics of the Benguet Igorots are the prettiness of the women and the ugliness of the men. Three pretty girls may be seen, one in Plate I, fig. 8, the others in Plate III, figs. 1 and 2. Benguet men are shown in Plate II, figs 1, 2, 3, 4, 5, and 6. The men of figs. 1, 2, 3, and 4 are modified Primitive in type as may be seen by their ears and physiognomy. The Iberian type is present in Benguet, modified in form, but distinctly European in physiognomy, as illustrated by fig. 6. The high head and long face, the moderately high nose—not broad and flat—the nostrils opening downward, and the ears without lobule and with everted concha and somewhat rolled-out helix stamp this man with Iberian characteristics. The accompanying fig. 5 of a younger man is distinctly modified Primitive in type, with broader head, shorter face, wider nose, and bowl-shaped ears. Evidence favors the view that the Benguet Igorots are more Primitive than those of Bontoc, which points to an infiltration into Benguet from the lowlands; Bontoc, being more inaccessible, has retained to a greater extent the earlier elements of the Iberian type that came from Europe, probably through India, in prehistoric times; or else there has been a migration into Bontoc of Iberians who did not reach Benguet. Evidence of the Indian Iberian is not lacking throughout the Philippines, a large part of the Iberian element having come in the early settling of the Philippines by Hindu Malays. The Iberian and the Primitive occur among all the Filipinos.

THE TINGIANS

Adjoining the Igorots on the west, and separating them from the Ilocanos of the coast, are the Tingians who are modified Iberian to some extent, as may be seen in Plate III, fig. 3, and

Plate IV, figs. 1, 2, 3, and 4. The women are pleasing in appearance, and the Tingian men are not unattractive. Their physiognomy is distinctive and different from that of the Iberians of Bontoc and Benguet. The Bontoc Iberians are purer in type, the Benguet Iberians are the least pure, and the Tingians are intermediate, each having a characteristic form that appears to have become somewhat stable and fixed as a type that can be differentiated. Endogomy and differences in the relative proportion of the type to start with have been largely influential in producing the differences, but habits and conditions have also played a part in molding the three groups in different directions.

THE KALINGAS

Turning next to the Kalingas, who live to the north of the three groups, another distinct modified Iberian type is encountered, different from, and purer than, any of the preceding. The man of Plate II, figs. 7 and 8, and the man of Plate V, fig. 1, represent them well, and the man of Plate V, fig. 2, is another representative member of the tribe although somewhat mixed in type. They have the wide open eyes of the East Indian, not shown well except in Plate V, fig. 1, and this, coupled with the relative purity of the Iberian type, indicates that they represent at least in part a remnant of that early East Indian element that must have entered the Philippines, and the type is purer here than elsewhere.

THE IFUGAOS

The Ifugaos who are south of the Kalingas and east of the other Igorots also have some of this Iberian element, as indicated by the woman of Plate IV, figs. 5 and 6, who is placed beside the Primitive Australoid Mañgyan woman (figs. 7 and 8) for comparison and contrast. The Mañgyans are largely of the Iberian types and probably of East Indian origin, as demonstrated in a previous study, but there is also the Negrito element in the interior, and the Primitive is present as well. Throughout the Archipelago these three types are fundamental—the Primitive, the Australoid, and the Iberian—with the Iberian predominant in local areas.

MINDANAO

Passing from Mindoro we may go to Mindanao, and in doing so we cross the Visayan Islands, the middle group of the Archipelago, between the two large islands, Luzon in the north, and

Mindanao in the south; and in the Visayas a modified Primitive type similar to the one shown in Plate V, figs. 3 and 4, may be seen.

The people of Mindanao are largely of four groups: the Moros of the south, the Subanuns of the north, the Bagobos of the Gulf of Davao, and the Bukidnons in the interior. A few Negritos are said to exist in the northeastern part of the island. Photographs of the last two groups are not available, therefore they are omitted necessarily.

The Subanuns are distinctly Iberian in character as may be seen in Plate V, figs. 5, 6, 7, and 8, and Plate VI, figs. 1 and 2, although mixed and modified Primitive and Australoid types are not altogether absent. The Iberians are unlike those of Luzon, and resemble the Moros from whom they were probably derived in large measure. Therefore, they are of more mixed Iberian type, having come through Arabia and being more recent in origin than the Indian Iberians. However, types similar to those of central Luzon may be seen, and the man of Plate V, fig. 6, is an example. This man resembles an Ilongot of a previous publication, and the two represent an early European migration that came directly through the intervening territory without great mixture on the way. They are not unlike European types that may be seen in the United States. Subanuns, as in Plate VI, figs. 5 and 6, are similar to the Bontoc Igorots of Plate I, figs. 6 and 7, although somewhat more Primitive. Types similar to this are found in Benguet, as the men in Plate II, figs. 3 and 4 show; also among the Bagobos, as is shown in Plate VIII, figs. 1 and 2. The ears of these people are mixed Primitive and might be termed the Australoid although simulating the Alpine. This modified Primitive form is a fundamental type of the Islands. The other Bagobo is also a fundamental type of the Islands, and resembles the Benguet Igorot of Plate II, figs. 1 and 2, the Bagobo of Plate VIII, figs. 3 and 4, and similar types elsewhere. The Igorot is more Primitive than the Bagobo, who is almost typical B. B. B. The square face, head, and ear are unmistakable.

The Moros are almost all modified Iberian types as may be seen in Plate VII, which portrays only high-class Moros—sultans and datos. The sharp nose with high bridge, the long face with pointed chin, and the ear of Iberian types, although somewhat modified and resembling the Alpine in Plate VII, figs. 3, 4, and 8, signify a derivative origin from Europe. The Moro

Iberians are different from the Iberians of Luzon, but similar to the Subanun Iberians. Arabian blood in the Moros may account for the difference. Three individuals of Mindanao in Plate IX represent the Bagobo, Subanun, and Moro, respectively, and the three persons are very much alike in physical characteristics, which is to be expected of the inhabitants of a single island.

This glimpse of inland Filipino types serves to impress one with the prevalence of the Iberians, especially among the leading men of the tribes, for it is true that such men are as a rule the ones whose photographs have been taken. The uniformity of distribution of the Iberian is exceeded only by the diversity of type, each group or tribe having an Iberian form different from the other groups. Thus the Iberian Kalingas and Bontoc Igorots are similar to the Hindu Iberians, the Moros and Subanuns are similar to the Moors or Arabs, and in the heart of Luzon and Mindanao are types similar to existing European types in America.

In addition to the Iberian types there are Primitive, modified Primitive, and Australoid types among the inland tribes, as well as those with modified Alpine and modified B. B. B. affinities, which represent forms of the Orient that are not of European origin, but have been modified by European types.

Therefore, it seems to me, from this and previous studies, that the fundamental types, Iberian, Primitive, and Australoid, have entered into the population of the Philippines throughout the Archipelago, and for that reason all the people of the Philippines are similar in type. The different islands, and different localities in any one island, have received varying proportions of the three fundamental types—sometimes pure, sometimes mixed with each other—coming from different places, where fusion had already fashioned a modified type; local conditions, endogamy or exogamy, inbreeding or breeding out, and differences of soil, climate,. food, and water have affected the groups in many ways with the result that one tribe differs from another at present, although individual members of the different tribes resemble each other. Other European types such as the Alpine and B. B. B. may have entered the Islands from time to time or the modified Alpine and B. B. B. types may be the result of combinations in various ways of the Iberian, Australoid, and Primitive.

Three distinct migrations from Europe are evident from the three modified Iberian forms; one from Europe direct, without mingling with intervening peoples, as represented by the almost pure European types in the heart of Luzon and Mindanao; one by way of India in which the types are the Indian and the so-called Malay; and one from Arabia and north Africa, the Mohammedan of history. There is also evidence among the Ilongots of another European element migrating through Siberia, possibly through China, and also from Japan. The Australoid type may antedate the Negritos, it may have resulted from them by crossing with other types, or it may have been brought in with the other types in the mingling migrations of the Europeans. The Primitive type is probably oriental in origin, although I have seen modified Primitive Europeans.

There have been waves and waves of migration, which have apparently come largely from the south, and each succeeding wave finds the drift of the preceding one and in receding leaves its own, sometimes penetrating farther than its predecessor, sometimes falling short and retiring before having reached the remaining portions of previous waves. A crescent would represent the form of the wave, the center advancing farther than the sides. Three crescents might be placed across the Archipelago to represent the three European migrations: The first would center in northern Luzon about the Ilongots, representing the purest European types, the crest of the wave having crossed central Mindanao, leaving traces among the Subanuns; the second crescent would cross the Island of Mindoro, but would have an eddy or advance point among the Kalingas and Bontoc Igorots; the third has its center in Sulu. The Mohammedan crescent advanced farther northward, but receded to Sulu when the Spaniards came.

The fields of greatest hopefulness for results in research, now as heretofore, are the interior of Luzon and the interior of Mindanao.

I have touched only the outskirts of the problem that confronts the racial anatomist in the Philippines, and whatever I have done is suggestive rather than conclusive.

ILLUSTRATIONS

Plate II, fig. 5, is from a photograph by Worcester; Plate V, figs. 3 and 4, and Plate VII, figs. 1, 2, and 7, are from photographs by Miller; Plate IX, fig. 3, is from a photograph by Ball; the photographer of Plate VII, figs. 5, 6, and 8, is unknown; the remaining cuts are from photographs by Martin.

PLATE I

FIGS. 1 and 2. A Bontoc man. This man has a notoriously bad character.
3 and 4. Front and side half-length pictures of Bontoc woman, showing typical ornaments, dress, and in some instances tattoo. The women as a rule tattoo the arms only.
FIG. 5. A Bontoc man.
6. A Bontoc man. Note this tremendously powerful neck.
7. The Bontoc man of fig. 6, side view.
8. Gabi, the youngest sister of Loyan and the prettiest girl of Pico. Taken in 1904.

PLATE II

FIGS. 1 and 2. Igorot men of Benguet.
3 and 4. Igorot men of Ambuklao and Kayapo (showing typical dress).
FIG. 5. Igorot man of Irisan, showing method of wearing blanket.
6. Acop, one of the wealthiest Igorots in the subprovince of Benguet.
7. A young Kalinga man, showing the peculiar form of the Kalinga eyes to special advantage.
8. Side view of young Kalinga man.

PLATE III

FIG. 1. Gabi, a girl of Trinidad, Benguet. Taken in 1901.
2. Two girls of Kalayan school. The taller one was teaching at Daklan at the time the picture was taken.
3. Full-length view of a young Tingian girl of Abra.

PLATE IV

FIGS. 1 and 2. Typical Tingians.
3 and 4. Tingian men, showing typical dress.
5 and 6. Ifugao women, showing typical dress and ornaments.
7 and 8. Young Mañgyan women, showing scaly skin disease which is common among the wild tribes of the Philippines and is particularly common among the Mañgyans inhabiting the lowlands of Mindoro.

PLATE V

FIG. 1. Man of Lubuagan, showing feather headdress.
2. The *presidente* of Nanong, perhaps the most influential man in the subprovince of Kalinga.
FIGS. 3 and 4. Views of a young Bukidnon man.

FIG. 5. A Subanun man of the District of Zamboanga. Note style of tying turban.

6. An old Subanun man of the District of Zamboanga. Note straggling gray beard and mustache. The occurrence of a beard among these people is unusual.

FIGS. 7 and 8. An old Subanun man of the District of Zamboanga. He has a relatively thick mustache and beard which is probably accounted for by the presence of some Arab blood.

PLATE VI

FIGS. 1 and 2. Subanun men with long hair.

3 and 4. Front and side views of typical Subanun man.

5 and 6. Subanun man who has his hair cut short and has light hair and mustache. His features are quite different from most of the Subanuns.

7 and 8. Front and side view of Subanun women of the Peyo River, near Sindangan Bay, Mindanao, showing physical characteristics, typical dress, and ornament. Note especially the load of necklaces worn by them.

PLATE VII

FIGS. 1 and 2. Typical Bilau men of Davao, Mindanao, showing dress and ornaments.

3 and 4. Front and side view of a Moro dato.

FIG. 5. Dato Mastura.

6. Judge Kali Punga.

7. Dato Dacula, at Zamboanga, Mindanao.

8. Moro youth, Samul Suwaan type.

PLATE VIII

FIGS. 1 and 2. Bagobo men, showing typical dress and ornaments. Note the spotted headdress, indicating that the warriors have killed enemies.

3 and 4. An old Bagobo man. The light spots with dark centers on the handkerchief wrapped about the head show that he has killed enemies. Note particularly the headpiece and embroidery. In side view, note the large opening in the lobe of the left ear, which evidently was at one time large enough to admit one of the ivory ear ornaments, but has now closed up somewhat.

PLATE IX

FIG. 1. A Bagobo, showing typical dress and ornaments. Note bead work on carrying bag.

2. View of a well-to-do Subanun woman, showing characteristic dress and ornaments. Note the numerous necklaces, the ear ornaments, embroidered upper garments, and the anklets.

3. Side view of young Yacan Moro.

MAP

Map of the Philippine Islands, showing distribution of inland tribes considered in this paper.

Vol VIII, Sec. D, No. 5, of this Journal was issued February 25, 1914.

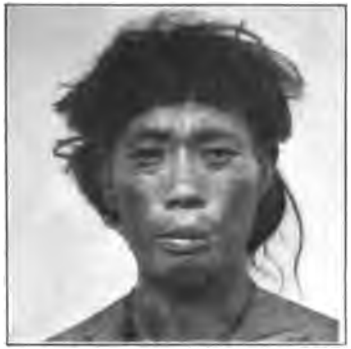


Fig. 1. Iberian.

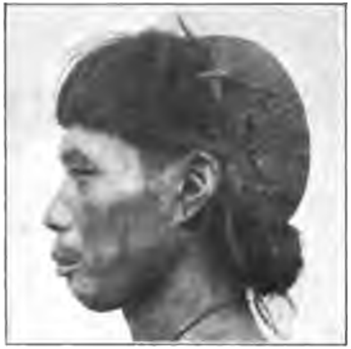


Fig. 2. Iberian.

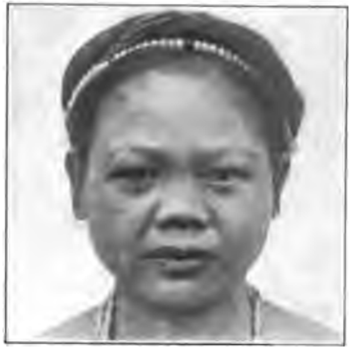


Fig. 3. Primitive.

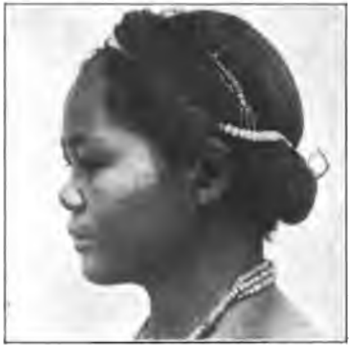


Fig. 4. Primitive.

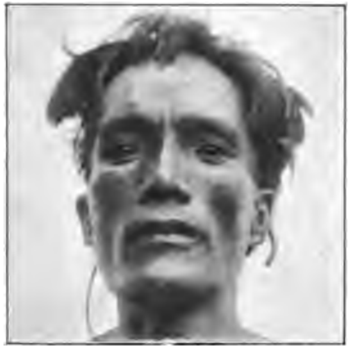


Fig. 5. Iberian.

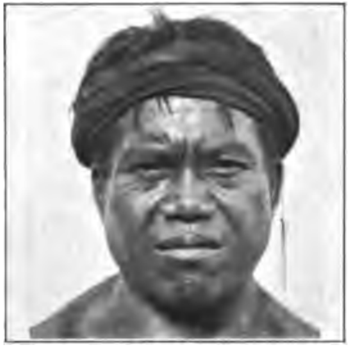


Fig. 6. Mixed.

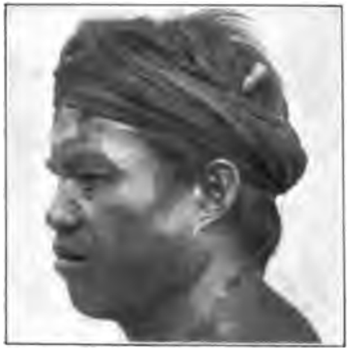


Fig. 7. Mixed.

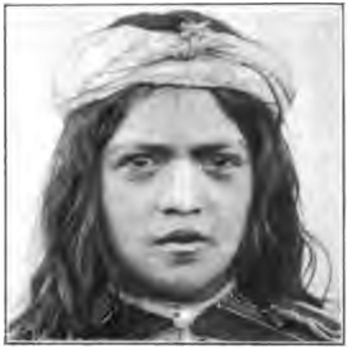


Fig. 8. Iberian.

PLATE I. IGOROTS AND A BENGUET GIRL.

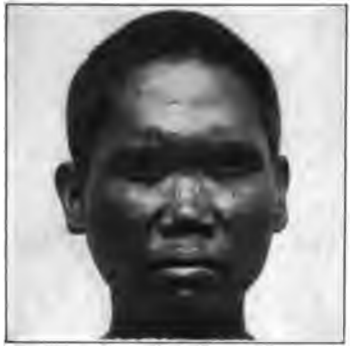


Fig. 1. Mixed B. B. B. ear.

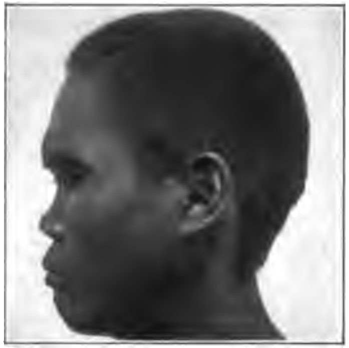


Fig. 2. Mixed B. B. B. ear.

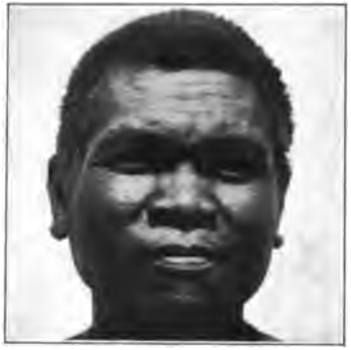


Fig. 3. Mixed Primitive ear.

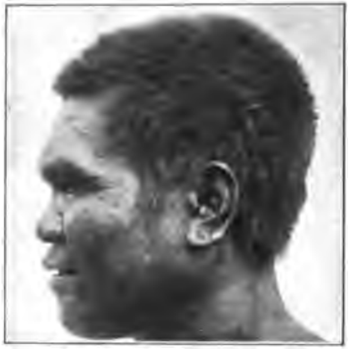


Fig. 4. Mixed Primitive ear.

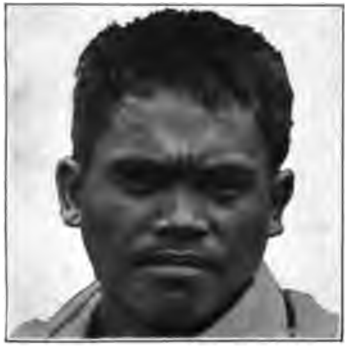


Fig. 5. Primitive ear.

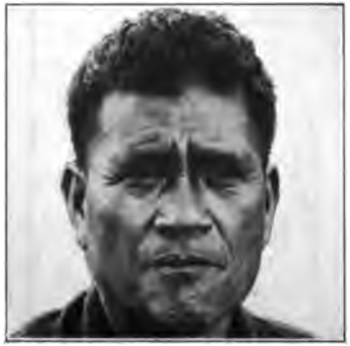


Fig. 6. Iberian ear.

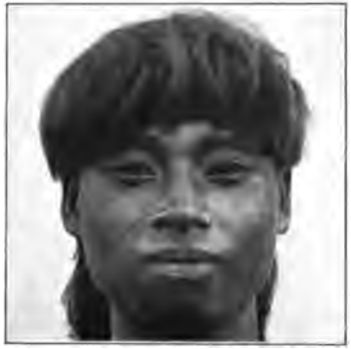


Fig. 7. Iberian ear.

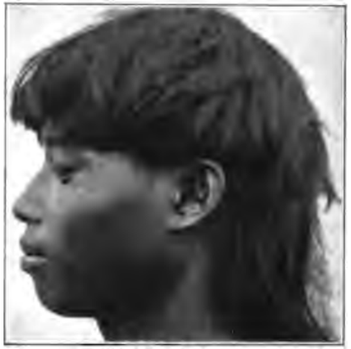


Fig. 8. Iberian ear.

PLATE II. BENGUET IGOROTS AND A KALINGA.

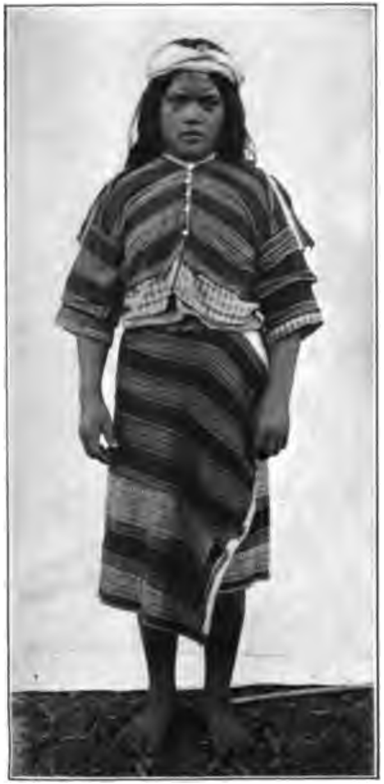


Fig. 1. A girl of Trinidad, Benguet.

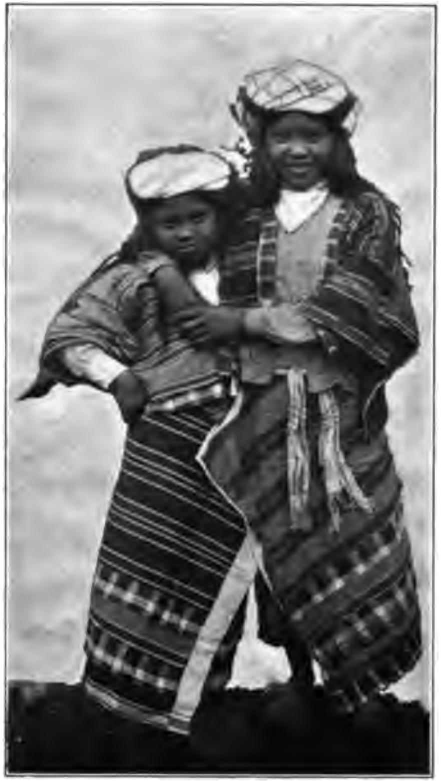


Fig. 2. Girls of Kayapao, Benguet.

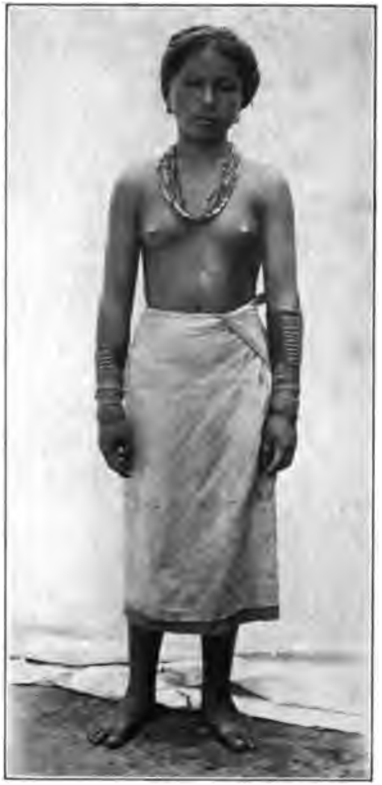


Fig. 3. A Tinglan girl of Abra.

PLATE III. TYPES OF LUZON.

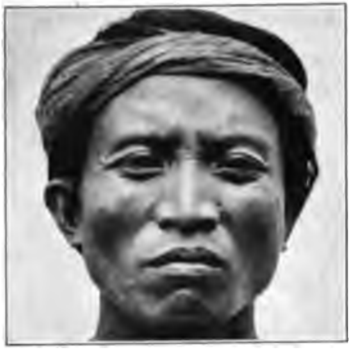


Fig. 1. Iberian.

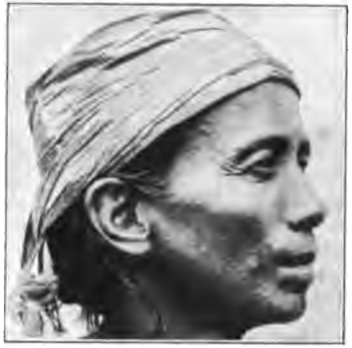
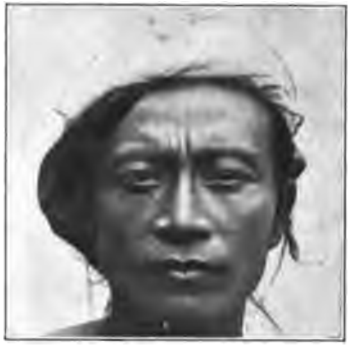


Fig. 2. Iberian.



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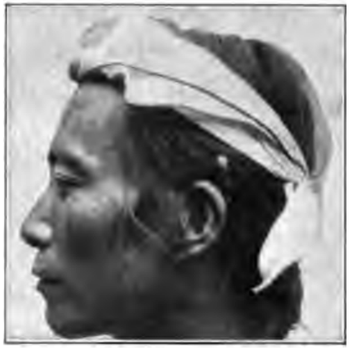


Fig. 4. Iberian.

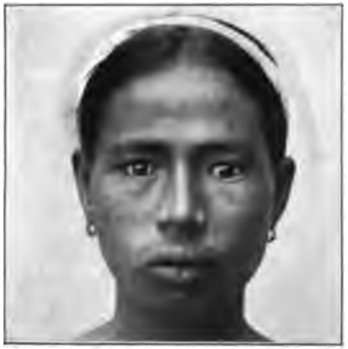


Fig. 5. Iberian.

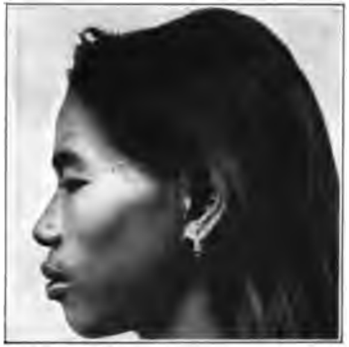


Fig. 6. Iberian.

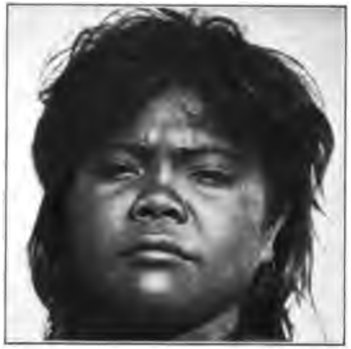


Fig. 7. Primitive.

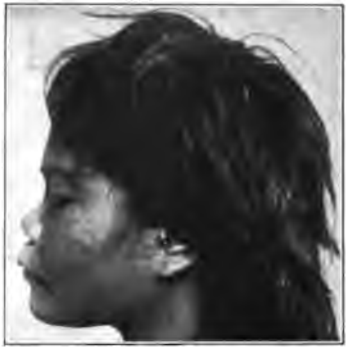


Fig. 8. Primitive.

PLATE IV. TINGIANS, AN IFUGAO WOMAN, AND A MANGYAN GIRL.

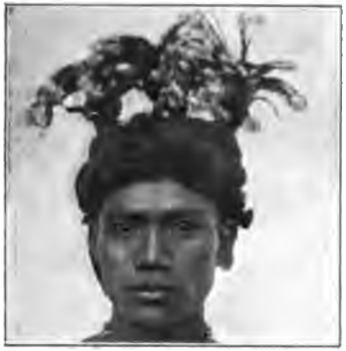


Fig. 1. Iberian ears.

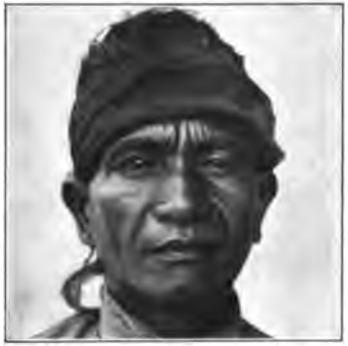


Fig. 2. Mixed ears.

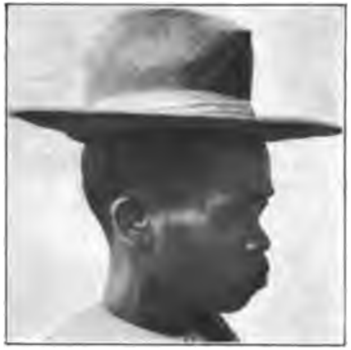


Fig. 3. Primitive ears.

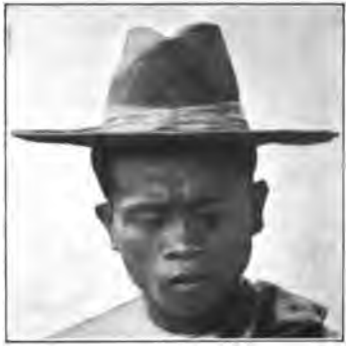


Fig. 4. Primitive ears.

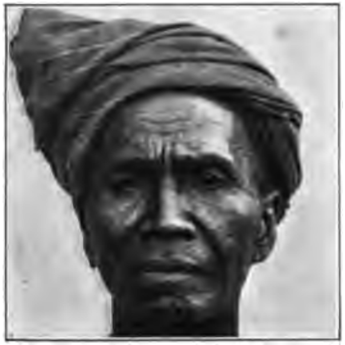


Fig. 5. Iberian ears.

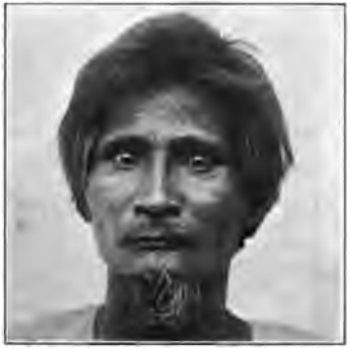


Fig. 6. Iberian ears.

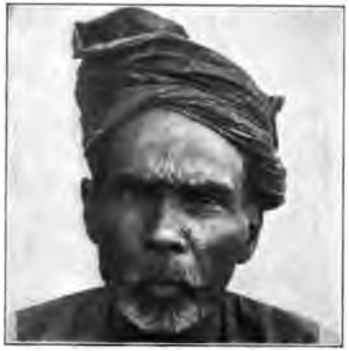


Fig. 7. Iberian ears.

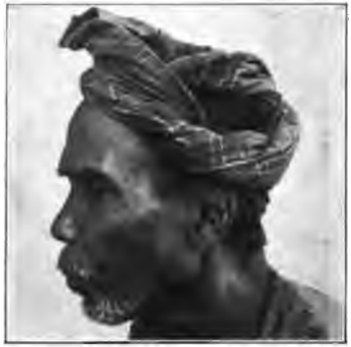


Fig. 8. Iberian ears.

PLATE V. KALINGAS, A VISAYAN, AND SUBANANS.

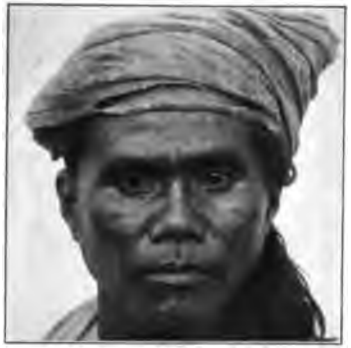


Fig. 1. Iberian ear.

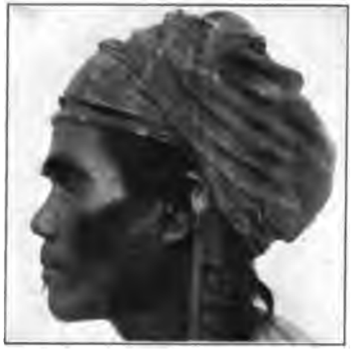


Fig. 2. Iberian ear.

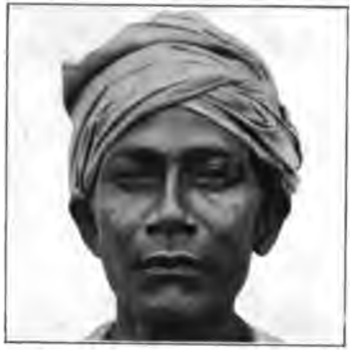


Fig. 3. Mixed ear.

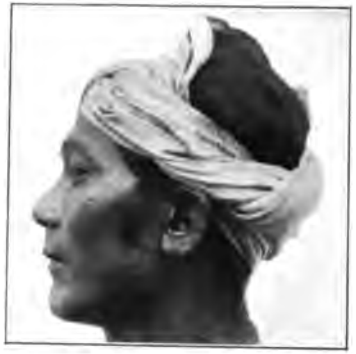


Fig. 4. Mixed ear.

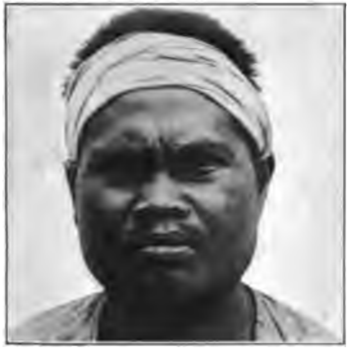


Fig. 5. Alpine-Primitive ear.

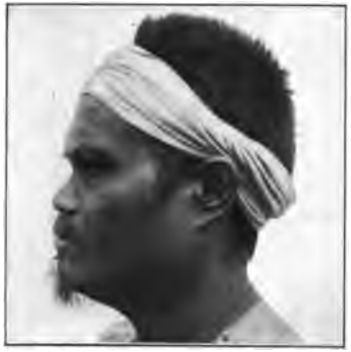


Fig. 6. Alpine-Primitive ear.

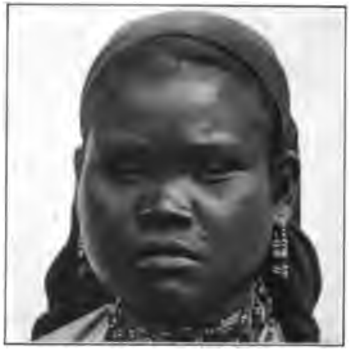


Fig. 7. Mixed-Primitive ear.

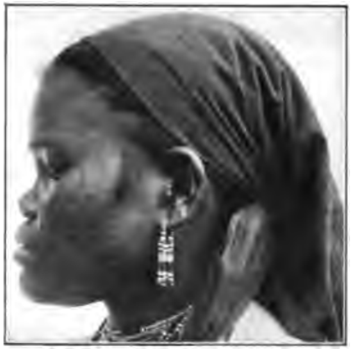


Fig. 8. Mixed-Primitive ear.

PLATE VI. SUBANANS.

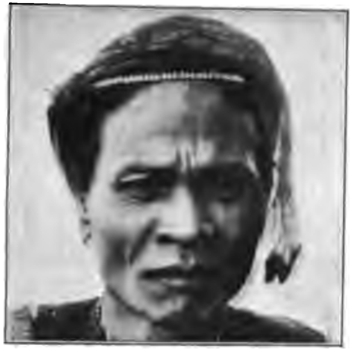


Fig. 1.

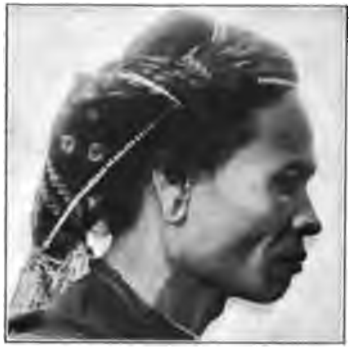


Fig. 2.

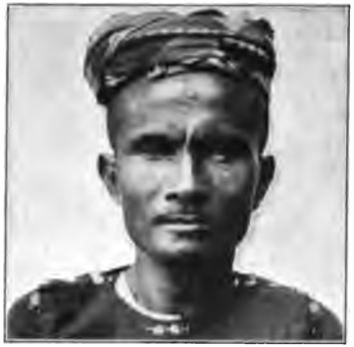


Fig. 3.

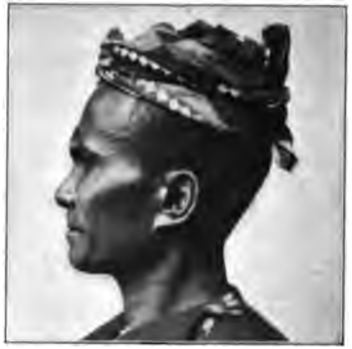


Fig. 4.

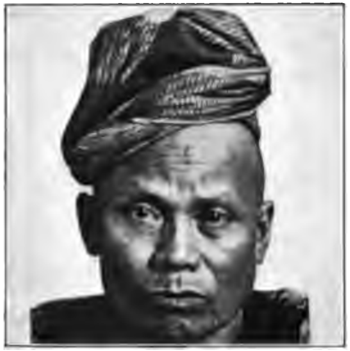


Fig. 5.

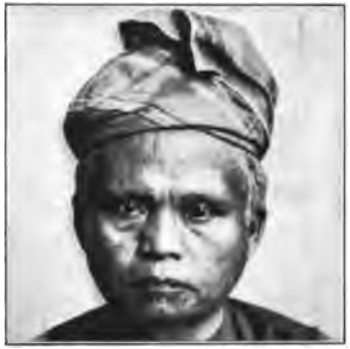


Fig. 6.

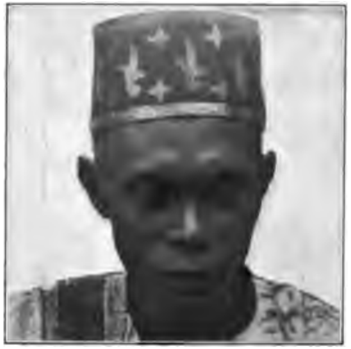


Fig. 7.

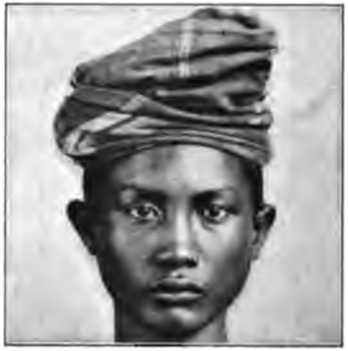


Fig. 8.

PLATE VII. MOROS. IBERIAN AND MODIFIED IBERIAN EARS.

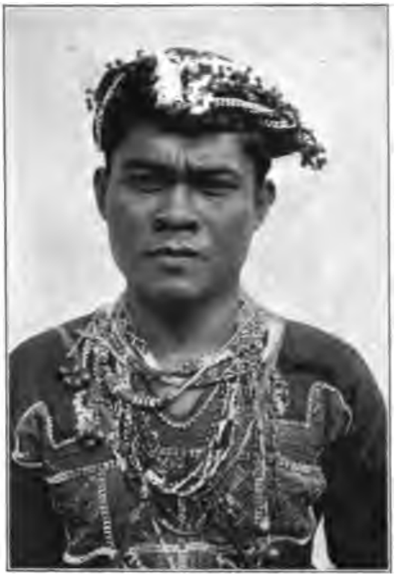


Fig. 1. Mixed Primitive ears. Alpine.

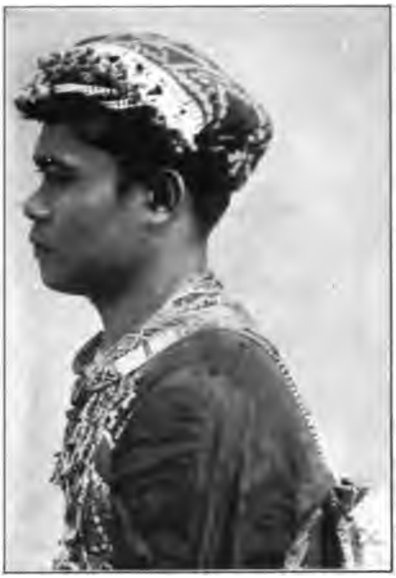


Fig. 2. Mixed Primitive ears. Alpine.

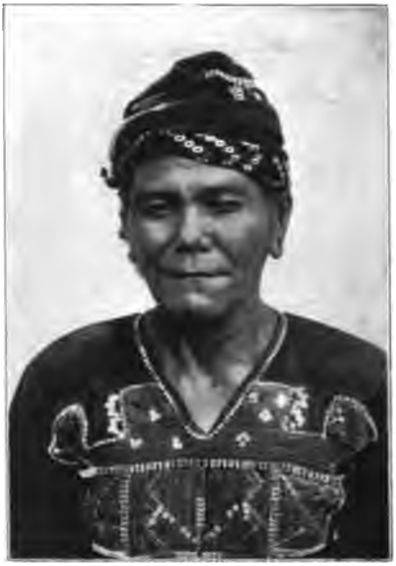


Fig. 3. Mixed B. B. B. ears.

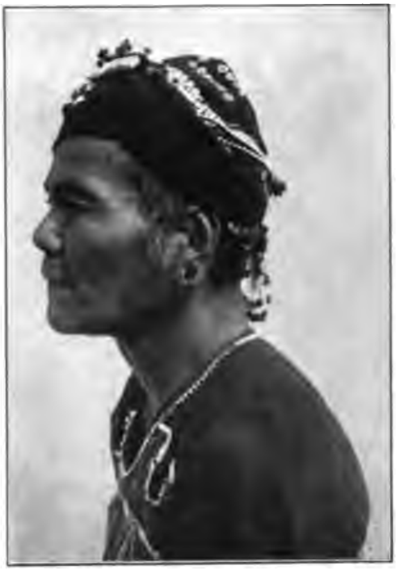


Fig. 4. Mixed B. B. B. ears.

PLATE VIII. BAGOBOS.

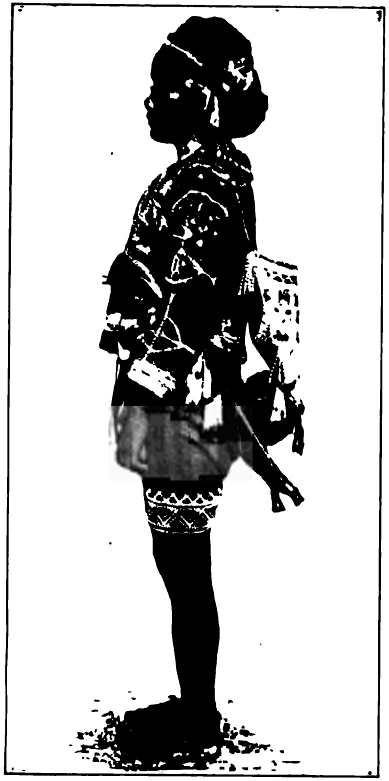


Fig. 1. A Bagobo.

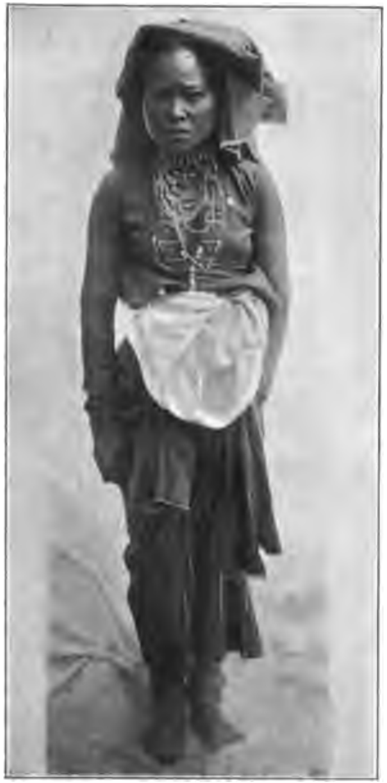


Fig. 2. A Subanun.

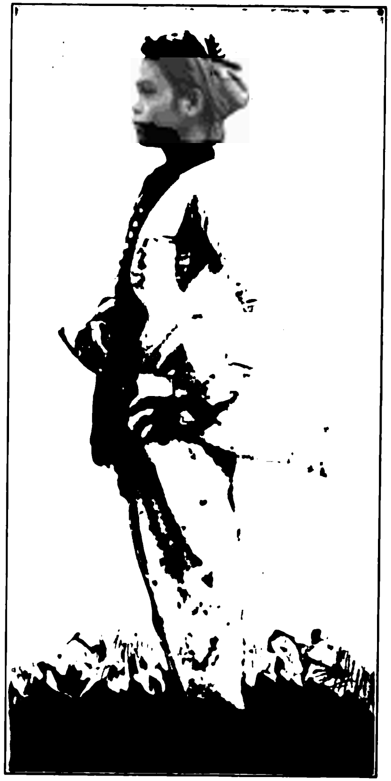
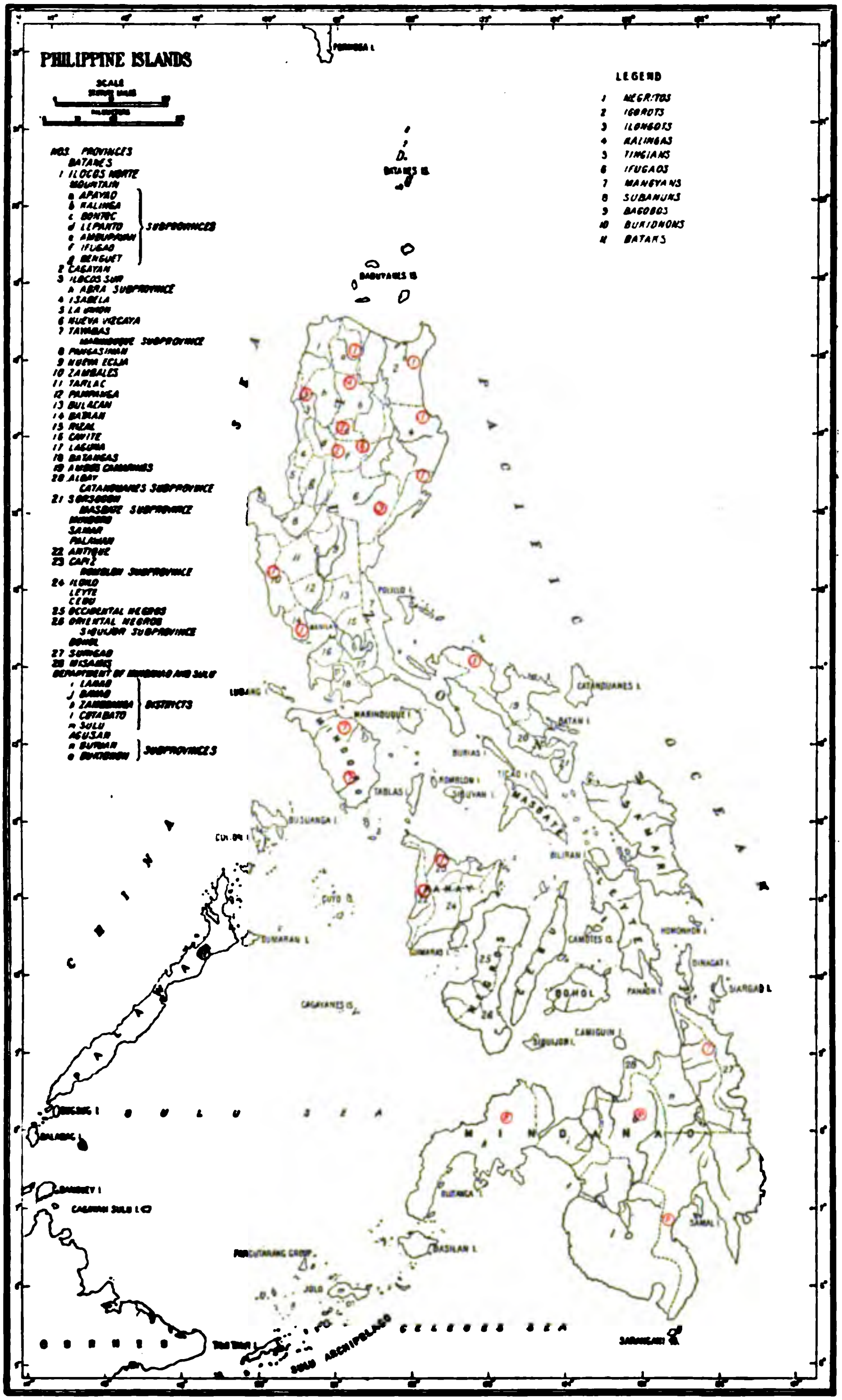


Fig. 3. A Moro.

PLATE IX. TYPES FROM MINDANAO.



MAP OF THE PHILIPPINE ISLANDS, SHOWING DISTRIBUTION OF INLAND TRIBES.

Not
Read Hypo-morphic for Prim
" Meso-morphic " Mesa
" Hyper-morphic " I

FILIPINO EARS: IV. ILONGOT AND MAÑGYAN

By Robert Bennett Bean

(*From the Anatomical Laboratory, Philippine Medical School, Manila, P. I.*)

Twenty plates

This is a study of contrasts and parallels. The Ilongots live in the interior of Luzon; the Mañgyans in the interior of Mindoro; both are said to have Negrito blood. Considering the individual as a whole and the characteristics of the individuals independently of each other, the two tribes are both alike and unlike in physical make-up, and other contrasts and parallels will develop as the study continues.

FRONT AND PROFILE HEAD VIEWS

Plate I

Four Mañgyans of Bulalacao, Mindoro, appear in this plate, and the four, although different in some respects, resemble each other in important characteristics. The Mañgyan of figs. 1 and 2 has modified Iberian ears, type A, and the Mañgyan of figs. 3 and 4 has modified Iberian, type B; the two have relatively long faces and straight noses and their general similarity is evident. European (East Indian?) blood lies back of these men somewhere in their ancestry. The two other Mañgyans, figs. 5, 6, 7, and 8, resemble types other than the European, although some resemblance to the latter may be seen. The man of figs. 5 and 6 has modified Alpine ears, wide face, prominent cheek bones, narrow, aquiline nose, and is similar to the North American Indian, especially in profile. The man in figs. 7 and 8 looks like a woman, and but for the brown color might be taken for a European. The face is rather wide, but not so wide as that of the man in figs. 5 and 6; the nose is long, high, slender, and straight; and the ears are modified Iberian, type A.

Plate II

By contrast with the Mañgyans of Plate I, the Ilongots of Plate II have short, broad faces, short broad noses that are depressed at the bridge and turned up at the tip, and ears that are not Iberian, although an indication of slight eversion of the concha is present; nor are they true Primitive ears, but a modified Primitive of peculiar type. The ear may be described as follows: Short and not broad, with overturned and inrolled upper helix, slightly everted concha, and small pendant lobule, resembling somewhat the true Negrito ear. It is found exactly as described, or somewhat modified, on all the Ilongot men and women, although on the latter it partakes more of the Primitive type. The Ilongots are modified Primitive people in contradistinction to the Mañgyans who are modified Iberians.

The hairy face of certain Ilongots is a noticeable feature, and one in striking contrast to the smooth physiognomy of the Malays in general. It would be of scientific value to determine the hereditary characteristics of the face hair, to determine if its presence and absence follow Mendel's laws, or if it blends in inheritance.

PLATE III

The Ilongots of this plate have longer faces and longer, straighter noses, with higher bridges than the Ilongots of Plate II, and the ear is more like the Alpine, although it still is distinctively the Ilongot ear. Varying quantities of hair appear on the face, from the Ilongots in figs. 1 and 2 with goatee and moustache to the smooth face of the man in figs. 7 and 8, which indicates that presence and absence of hair on the face may blend in heredity.

PLATE IV

The Ilongot women of this plate are decidedly Primitive in type, and also the Mañgyan girl (figs. 7 and 8), although the noses are not broad and the nostrils do not turn forward to such a degree as in the pure Primitive. Therefore, they would come under the head of modified Primitive people, or blends of the Primitive type. The ear is characteristically Primitive, although retaining the Ilongot type already noted. The small, prominent forehead, the vertical profile of the face, and the small, receding chin complete the picture of a Primitive type. The Mañgyan girl, so much like the Ilongots, is only another parallel between the two tribes.

PLATE V

To continue the parallel and contrasts, a Mañgyan man (figs. 1 and 2) is placed beside an Ilongot woman (figs. 3 and 4) and an Ilongot man (figs. 5 and 6) is placed beside a Mañgyan man (figs. 7 and 8). All have ears of a like kind, a combination of Primitive and Iberian C not unlike the ear of the Igorots. The ear is oblong, with everted concha, square lobule, and slightly overturned upper helix, and it stands almost flat against the head. In many respects this ear resembles the B. B. B. In conjunction with this ear the nose is straight and the face is oval and elongated, and projects slightly forward, except in the Ilongot man where the Primitive characteristics of the Ilongots are retained.

PLATE VI

This plate shows a series of gradations in ear form from the modified Iberian (fig. 1) to the modified Primitive in fig. 4, and paralleling the change in ear form is the transition from a straight nose with a high bridge to a retroussé with depressed bridge. Three of the individuals are Mañgyans (figs. 1, 3, and 4), and one is an Ilongot (fig. 2). Two of the Mañgyans, a man and a woman (figs. 3 and 4), are more Primitive than the Ilongot who is a modified Iberian, which may indicate that the Ilongots represented by the photographs are not all modified Primitives and the Mañgyans are not all modified Iberians.

The Mañgyan woman from Bacó River (figs. 5 and 6) is a Primitive with Primitive nose, face, and ears; whereas the Mañgyan woman from Bulalacao (figs. 7 and 8) is a modified Primitive as indicated by the same features modified, which is additional evidence of the Primitive among the Mañgyans. The Primitive Mañgyan girl of figs. 7 and 8, Plate IV, is another link in the chain of evidence. Here, as elsewhere, the women are more Primitive than the men.

PLATE VII

The Mañgyan of figs. 1 and 2 is a modified Primitive man, and the one of figs. 3 and 4 is a modified Iberian B with Alpine characteristics in ear form and physiognomy, which indicate that the Primitive form is not confined to the women. The two Mañgyans of figs. 5, 6, 7, and 8 are supposed to have Negrito blood because of the curly hair of the one and the Negrito features of the other. However that may be, the one is a modified Primitive and the other a modified Australoid-Iberian, which does not exclude the possibility of Negrito blood. The ears have Negritoid qualities, especially those of the man in figs. 7 and 8. If it be true that this man is part Negrito, he is an evident example of the dominance of straight hair over kinky in a population where straight hair predominates, else he is a pure recessive from a Negrito cross.

PLATE VIII

The Mañgyans of this plate form a separate group coming from Lalanigan, but as usual both Primitive and Iberian characteristics appear, although the noses of these Mañgyans are inclined toward the Australoid type—broad, straight, and heavy. The woman of figs. 1 and 2 has almost pure Iberian ears, type B, of the kind often seen on American Negroes. The men of figs. 3, 4, 5, and 6 have modified Primitive ears and the man of fig. 7 has modified Iberian ears, type B, that are not so pure as those of the woman of figs. 1 and 2. The woman of fig. 8 has ears that resemble the Iberian in the lower part and the Primitive in the upper part, but it is difficult to determine the exact character of the ear in the last two individuals because only the side view is given and the position is bad in both. This group of Mañgyans cannot be differentiated from Negroes by ear form, and although the hair is straight the features are not unlike those of the Negritos.

PLATE IX

Negrito blood is evident in at least one man in this plate (fig. 3), and it may be present in others, especially in the man of figs. 1 and 2 who has wavy hair, Negrito ears (modified Primitive), and Negrito features. The man of fig. 4 has modified Iberian ears, type B. The man of figs. 5 and 6 is a modified Primitive in ear form and features, with the Mongoloid fold at the inner canthus of the eye, which is not a Negrito characteristic. The only other individual in this series of pictures with a well-marked inner fold is the Igorot of Plate V, figs. 5 and 6, who is also a modified Primitive with ears that resemble the ears of some Siberian women photographed by Frau Dina Jochelson-Brodsky.[1] The three women are from eastern Siberia, north of the Sea of Okhotsk, and are modified Primitive in type. They are of the Turko-Mongol stock, and are related to the Eskimo on the one hand and the Chinese on the other. This stock may have entered the Philippines through the Chinese or Japanese, and it is probable that the men with the Mongoloid fold of the inner canthus mentioned above have derivative Mongolian blood somewhere in their ancestry. This assertion is supported by the similarity of the Siberians and Ilongots in respect to their Primitive features and ear forms, and one is led to believe that the same stock exists in the two peoples, however it came about.

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[1] *Arch. f. Anthrop.* (1906), 5, Pl. II, fig. 1, and Pl. III, figs. 1 and 2.

PLATE X

The Ilongots of this plate are modified Alpine in respect to ears and physiognomy, with Primitive attributes well marked in the man and woman in the lower part of the plate. The man of figs. 1 and 2 resembles the North American Indian, and the one in figs. 7 and 8 resembles the Igorots, although the ears are Ilongot in character and not unlike true Negrito ears. The man of figs. 3 and 4 and the woman of figs. 5 and 6 have Alpine ears with modified Primitive characteristics. The woman is more Primitive than the man.

PLATE XI

In marked contrast to the smooth-haired Ilongots of the previous plates are the curly-haired Ilongots of Plate XI who are supposed to be of mixed Negrito blood. The evidence is in the hair alone.

They vary in character from the decided Primitive of figs. 1 and 2 to the modified Primitive or Alpine in fig. 6, with varying intensity of hair curl in decreasing rate to the woman of figs. 7 and 8 with straight hair. If the curly hair is due to Negrito blood, the indication is that Primitive and Negrito are synonymous terms. However, it is not impossible that the curly hair of the Negrito is a character separable from the type of the individual, and thus may occur on pure Iberians as noted on one Zambales Negrito, or it may occur on pure Primitives as seen in this instance. The hair of the pure Iberian Zambales Negrito was kinky, and the hair of this pure Primitive is curly, which indicates also that there may be blending in hair form.

PLATE XII

The men of this plate have familiar faces similar to those that have often been seen in the backwoods of the Atlantic States in America, and their ears partake of a modified Alpine type. The two men in the upper part of the plate have more Iberian than Primitive in their make-up, and the two in the lower part have more Primitive than Iberian. The curly hair of the man in figs. 5 and 6 may indicate Negrito blood. The man in figs. 7 and 8 is not unlike pictures I have seen of the Ainos. This element may have existed among the early Ilongots and has persisted only in this group. Such types as these are found also in Mindanao, and may be remnants of what has been called the Indonesian, which Montano maintains may be encountered in the interior of Luzon and Mindanao. It cannot be denied that there are European types in these places, and this may be only a rare type of their expression in a remnant that has remained little contaminated by surrounding blood. The hairy Ilongots may be referred also to the hairy Ainos, and if not derived from them are of the same stock.

PLATE XIII

The women of this plate partake largely of modified Iberian characteristics in gradually increasing amount from fig. 1 to fig. 8, although the Primitive characteristics are also present. These women resemble Igorot women more than Ilongot, and there must have been some infiltration of Igorots from the west. The women of figs. 1, 2, 7, and 8 are strikingly like the Igorot women of Bontoc or Benguet. Both women have Igorot ears (Iberian C modified). These individuals pertain to the early Indonesian of Montano and other writers.

To summarize: The Mañgyans are largely Iberian and the Ilongots are largely Primitive. The former give evidence of Negrito characters, especially those from the interior of the Island of Mindoro. The Ilongots, especially those of Oyao and Canadem, are similar to Siberians of the Mongol stock, which may be due to Chinese elements among them. Some Ilongots also resemble Negritos and others resemble Igorots. The Ilongots have hairy faces, whereas the Mañgyans' faces are glabrous.

VIEWS OF THE FULL FIGURE

PLATES XIV AND XV

The four men in Plate XIV are Mañgyans, and the four in Plate XV are Ilongots. The Mañgyans are long legged, the Ilongots short legged, an indication of Iberian in the former and Primitive in the latter. Other characteristics that have been described may be seen, such as the long face and long nose of the Mañgyans and the broad face and broad nose of the Ilongots. The headdress and belts of the two peoples are the same in style but different in structure. The clout of the two is different, the apron of the Mañgyan being an additional distinction.

PLATE XVI

The difference noticed in Plates XIV and XV between the long legs of the Mañgyans and the short legs of the Ilongots is emphasized in the four men of this plate, and the other characteristics may also be seen. The necklaces of the Mañgyan men are very elaborate, and add distinction to their long necks.

PLATE XVII

The women of this plate well represent the Mañgyan group, from the young girl on the left who is mixed Primitive to the old woman on the right who is Australoid, probably part Negrito. The changes in the breasts with advancing age may be seen also. Several styles of skirts are to be noted, from its complete absence, through the small apron, to the full skirt.

PLATE XVIII

The Mañgyans of Banganay have much Negrito blood, and the various conditions of wavy and curly, to almost kinky, hair may be seen in this plate. The long and short legs, the modified Iberian ears, the modified Primitive ears, and the Australoid noses are to be noticed. These are the remnants of Negritos said by Meyer to exist in Mindoro, yet they are Mañgyans not greatly unlike others that have been portrayed.

PLATES XIX AND XX

The Ilongots of these plates give evidences of intermixture with people having longer legs than themselves, because they have legs of intermediate length, whereas those of the Ilongots are usually short. Their features and ears are more Igorot than Ilongot, although the Ilongot characters are present in both. Their costumes are similar to those of other Ilongots but more elaborate, and certain points of similarity to the Mañgyans may be seen, such as the apron and the neck ornaments, although these are only incidental in the make-up of the fully armed warrior.

To summarize the full figures: The Mañgyans are long legged, the Ilongots short legged, although some of them have legs of intermediate length; from which it may be inferred that the Ilongots are more Primitive and Alpine than the Mañgyans, who are more Iberian and Australoid than the Ilongots.

CONCLUSIONS

The presence of Negrito types among the Mañgyans, with straight hair and glabrous faces, indicates that these two characters are dominant in a population where they predominate, and the two characters may follow Mendel's laws in cross mating.

The presence of all grades of hair from the kinky to the curly and straight, and the presence of all grades of abundance of hair on the face from full heads to the glabrous condition, indicates also that these characters blend in heredity.

The Mañgyans who resemble the Negritos are more like the Mariveles Negritos than like those of other parts of the Philippines, whereas the Ilongots that resemble the Negritos are more like the Negritos of other parts of the Philippines and less like those of Mariveles than are the Mañgyans.

The Mañgyans of the interior resemble Negritos; those of the coast resemble Europeans. The Ilongots of Oyao and Canadem resemble the Siberian type; other Ilongots, the European type; others, the hairy Aino; and yet others are modified Negritos.

ILLUSTRATIONS[2]

Plates I to VII and XIII to XVII; Plate IX, figs. 4 to 6; Plate X, figs. 1, 2, 7, and 8; Plate XI, figs. 1, 2, 7, and 8; and Plate XII, figs. 1 to 6 are from photographs by Charles Martin. Plate XVIII is from photographs by Dean C. Worester. Plate X, figs. 3 to 6; Plate XI, figs. 3 to 6; Plate XII, figs. 7 and 8; and Plates XIX and XX are from photographs by Merton L. Miller.

PLATE I. MAÑGYANS

Figs. 1, 2, 3, 4, 7, and 8. Front and profile views of Mañgyans of Bulalacao, Mindoro. Note long, wavy hair and light beards, showing admixture of Negrito blood. Note effeminate features of man in figs. 7 and 8. Figs. 5 and 6. A Mañgyan chief.

PLATE II. ILONGOTS

Figs. 1 and 2. Front and profile view of typical Ilongot man. Figs. 3 and 4. Front and profile views of Ilongot man. Note the very scanty beard and earrings in the upper margins of the ears. Figs. 5. 6, 7, and 8. Front and profile views of typical adult Ilongots. Note typical Ilongot hair net.

PLATE III. ILONGOTS

Figs. 1 and 2. Front and profile views of middle-aged Ilongot man. Note the remarkable features of this individual who is of a type far superior to that of the majority of his tribe. Figs. 3, 4, 5, and 6. Front and profile views of typical Ilongot men. Figs. 7 and 8. Front and profile views of young Ilongot man.

PLATE IV. ILONGOT AND MAÑGYAN WOMEN

Figs. 1 and 2. Front and profile views of Ilongot woman. Figs. 3 and 4. Front and profile views of Ilongot girl just approaching maturity. Figs. 5 and 6. Front and profile views of mature, married Ilongot woman, showing typical headdress. Figs. 7 and 8. Front and profile views of young Mañgyan girl.

PLATE V. MODIFIED IBERIAN EARS, TYPE C

Figs. 1 and 2. Front and profile views of Mañgyan man. Figs. 3 and 4. Front and profile views of adult Ilongot woman. Figs. 5 and 6. Front and profile views of Ilongot man in his prime, of Oyao, Province of Nueva Vizcaya, Luzon. He shows with great plainness the admixture of Negrito blood. Figs. 7 and 8. Mañgyan man of Bulalacao, Mindoro.

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[2] The descriptions of these photographs are taken from the catalogue of Dean C. Worcester.

PLATE VI. TRANSITIONAL MAÑGYAN EAR FORMS, IBERIAN TO PRIMITIVE

FIG. 1. Profile view of Mañgyan man of Bulalacao, Mindoro. Modified Iberian C. FIG. 2. Profile view of typical Ilongot man of Oyao, Nueva Vizcaya. Modified Iberian C. FIG. 3. Profile view of Mañgyan man of Bulalacao, Mindoro. Modified Primitive. FIG. 4. Profile view of Mañgyan woman of Bulalacao, Mindoro. Modified Primitive. FIGS. 5 and 6. Front and profile views of Mañgyan woman of the Baco River, Mindoro. Primitive. FIGS. 7 and 8. Front and profile views of Mañgyan girl of Bulalacao, Mindoro. Modified Primitive.

PLATE VII. MIXED MAÑGYANS

FIGS. 1 and 2. Front and profile views of an old Mañgyan man of the Baco River, Mindoro. Modified Primitive. FIGS. 3 and 4. Front and profile views of Mañgyan man of the Baco River, Mindoro. Modified Iberian-Alpine. FIGS. 5 and 6. Front and profile views of typical Mañgyan man, showing particularly strong evidence of Negrito blood. Modified Primitive. FIGS. 7 and 8. Front and profile views of Mañgyan man of Bulalacao, Mindoro. Modified Australoid.

PLATE VIII. NEGRITO MAÑGYANS OF LALAUIGAN, MINDORO

FIGS. 1 and 2. Front and profile view of a Mañgyan woman. Modified Iberian B. FIGS. 3 and 4. Front and profile views of Mañgyan man. This man is especially tall for a Mañgyan, and has a perceptible moustache and beard. Modified Primitive. FIGS. 5 and 6. Front and profile views of a young Mañgyan man. Modified Primitive. FIG. 7. Profile view of a Mañgyan man. Modified Primitive. FIG. 8. Profile view of a Mañgyan woman. Modified Primitive.

PLATE IX. MIXED MAÑGYANS OF BANGANAY, MINDORO

FIGS. 1 and 2. Profile and front view of Mañgyan man. Modified Primitive. FIG. 3. Front view of Mañgyan man, having every indication of Negrito blood. Note his curly hair and flat nose. Pure Negritos are not known to exist in Mindoro, but a man of this type affords ample proof that they formerly existed there. Australoid. FIG. 4. Front view of a Mañgyan man who had received a terrible wound in a fight. This is a most unusual occurrence as the Mañgyans are extremely pacific among themselves and very friendly toward outsiders. Modified Iberian B. FIGS. 5 and 6. Front and profile views of Mañgyan man of Bulalacao, Mindoro. Modified Primitive.

PLATE X. MODIFIED ALPINE AND PRIMITIVE ILONGOTS

FIGS. 1 and 2. Front and profile views of middle-aged Ilongot man. Note the remarkable features of this individual, who is of a type far superior to that of the majority of his tribe. Modified Alpine. FIGS. 3 and 4. Front and profile views of Ilongot man of Dupax, Nueva Vizcaya. Modified and Alpine-Primitive. FIGS. 5 and 6. Front and profile views of Ilongot woman of Sugat, Nueva Vizcaya. Modified Primitive. FIGS. 7 and 8. Front and profile views of Ilongot man of Delapping, Nueva Vizcaya, of the bearded type. Modified Primitive.

PLATE XI. CURLY- AND STRAIGHT-HAIRED ILONGOTS

FIGS. 1 and 2. Front and profile views of bearded type of Ilongot, of Delapping, Nueva Vizcaya, showing painly admixture of Negrito blood. FIG. 3. Front view of Ilongot man of Kauayan, Nueva Vizcaya. FIG. 4. Profile view of Ilongot man of Kauayan, Nueva Vizcaya. FIG. 5. Front view of Ilongot man of Gading, Nueva Vizcaya. FIG. 6. Profile view of Ilongot man of Sugat, Nueva Vizcaya. FIGS. 7 and 8. Front and profile views of Ilongot woman of Canadem, Nueva Vizcaya.

PLATE XII. HAIRY ILONGOTS

FIGS. 1 and 2. Front and profile views of old man of Delapping, Nueva Vizcaya. Note his gray hair and beard. He has lost most of his teeth. Modified Iberian. FIGS. 3, 4, 5, and 6. Ilongot men of Delapping, Nueva Vizcaya, of the bearded type, showing plainly the admixture of Negrito blood. Modified Iberian and modified Primitive, respectively. FIGS. 7 and 8. Front and profile views of an old Ilongot man of Dupax, Nueva Vizcaya. Modified Primitive.

PLATE XIII. MODIFIED IBERIAN ILONGOT WOMEN

FIGS. 1 and 2. Front and profile views of young Ilongot woman, of Canadem, Nueva Vizcaya. FIGS. 3, 4, 5, 6, 7, and 8. Front and profile views of Ilongot women of Delapping, Nueva Vizcaya.

PLATE XIV. MAÑGYAN MEN

FIGS. 1, 2, and 3. Mañgyans of Bulalacao, Mindoro. FIG. 4. A Mañgyan chief of Bulalacao, Mindoro. The rattan about the waist was stained a bright scarlet.

PLATE XV. ILONGOT MEN

FIG. 1. Adult Ilongot man of Oyao, Nueva Vizcaya. The typical Ilongot ornaments and hair net may be seen particularly well in this photograph. Note especially the metal band about the left arm and the shell girdle. Also the admixture of Negrito blood, evidenced by wavy hair and scanty beard. FIG. 2. Ilongot man of Canadem, Nueva Vizcaya, showing typical dress. Note the very scanty beard and earrings in the upper margins of the ears and the ornamental rattan and braided cord about the waist. FIG. 3. Ilongot man of Oyao, Nueva Vizcaya. This man shows with great plainness the admixture of Negrito blood. FIG. 4. Typical Ilongot man of Canadem, Nueva Vizcaya. Note the hair net, shell girdle, and light growth of beard.

PLATE XVI. MAÑGYANS AND ILONGOTS

FIG. 1. Mañgyan man of Bulalacao, Mindoro. FIG. 2. Young Ilongot man. FIG. 3. Typical Ilongot man. Note beard and long hair. FIG. 4. Mañgyan of Bulalacao, Mindoro.

PLATE XVII. MAÑGYANS

FIG. 1. Typical Mañgyan woman of the Baco River, Mindoro. FIG. 2. Mañgyan woman of the Baco River, Mindoro, showing typical dress. FIG. 3. Mañgyan girl of Bulalacao, Mindoro, showing typical dress. FIG. 4. Old Mañgyan woman of the Baco River, Mindoro, showing evidence of Negrito blood.

PLATE XVIII. MAÑGYANS OF BANGANAY, MINDORO. MIXED NEGRITOS OF THE AUSTRALOID TYPE

FIG. 1. Mañgyan about to throw a lance. FIG. 2. Mañgyan, full-length front view, showing relative size. This man has very evident indications of Negrito blood. FIGS. 3, 4, and 5. Full-length front view of three Mañgyan men standing.

PLATE XIX. TYPICAL ILONGOTS OF DUPAX, NUEVA VIZCAYA

FIG. 1. Ilongot man armed. FIG. 2. Ilongot man, fully armed, profile view. FIG. 3. Ilongot man, profile view. Note headdress made of the head of a hornbill (*Hydrocorax*).

PLATE XX. TYPICAL ILONGOTS

FIG. 1. Ilongot man of Gading, Nueva Vizcaya. FIG. 2. Ilongot man of San José, Province of Tayabas, Luzon.

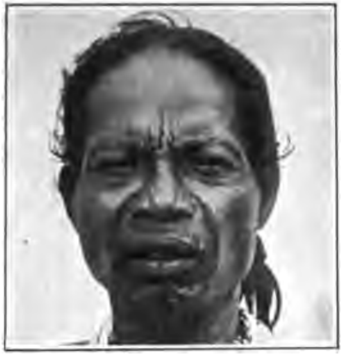


Fig. 1. Iberian A.

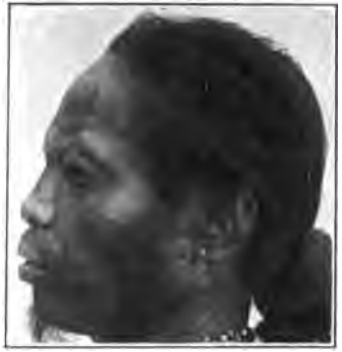


Fig. 2. Iberian A.

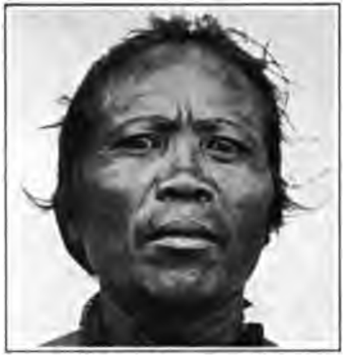


Fig. 3. Iberian B.

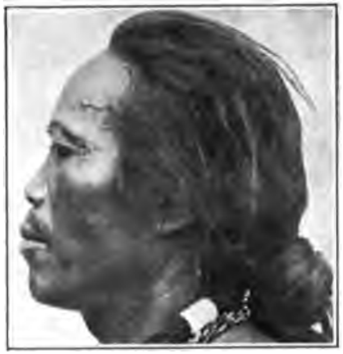


Fig. 4. Iberian B.

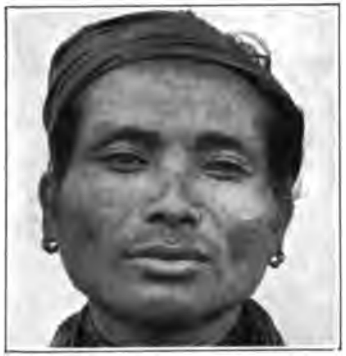


Fig. 5. Modified Alpine.

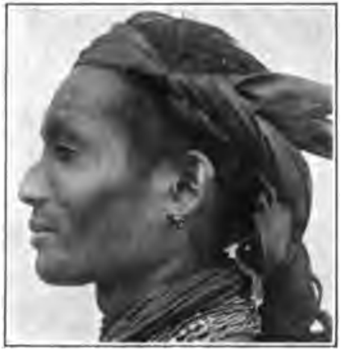


Fig. 6. Modified Alpine.

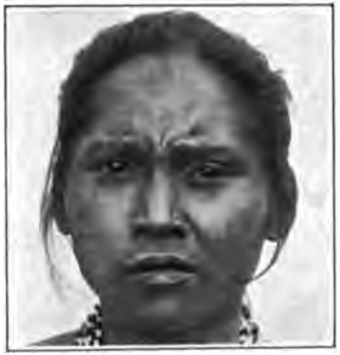


Fig. 7. Iberian A.

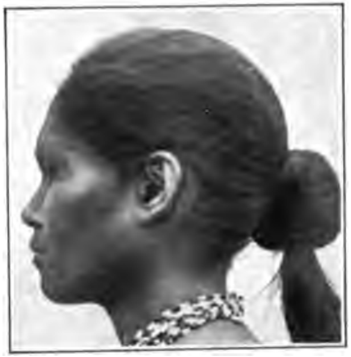


Fig. 8. Iberian A.

PLATE I. MANGYANS.

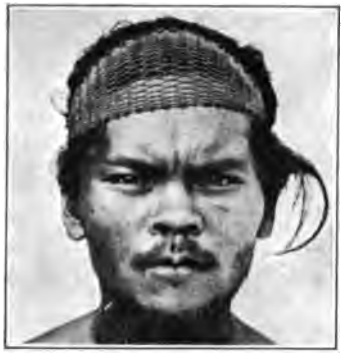


Fig. 1.

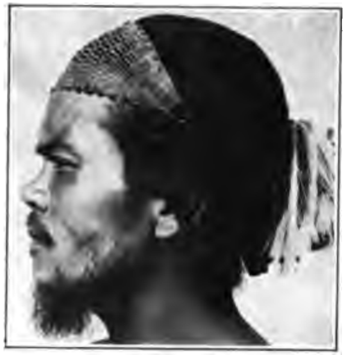


Fig. 2.

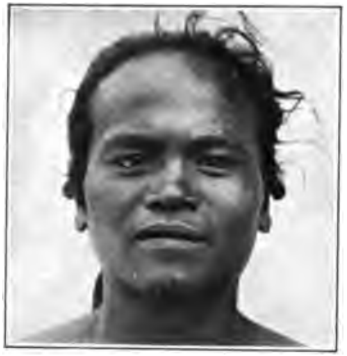


Fig. 3.

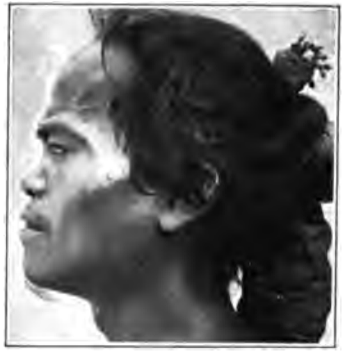


Fig. 4.

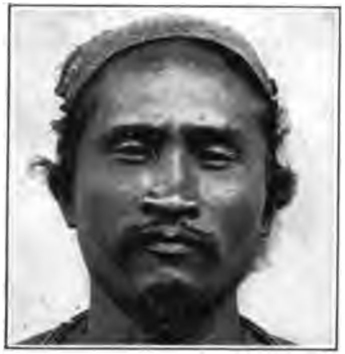


Fig. 5.

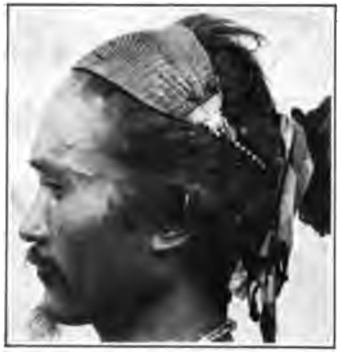


Fig. 6.

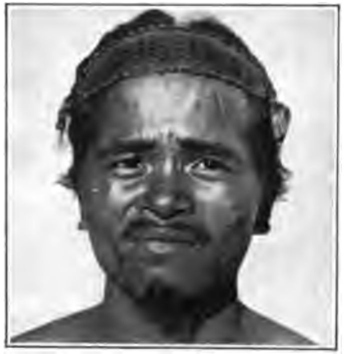


Fig. 7.

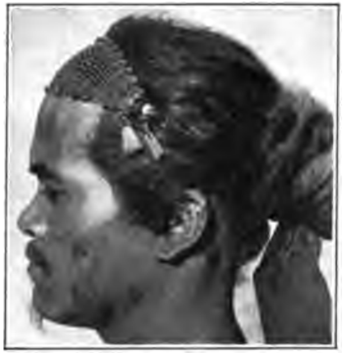


Fig. 8.

PLATE II. ILONGOTS. MODIFIED PRIMITIVE.

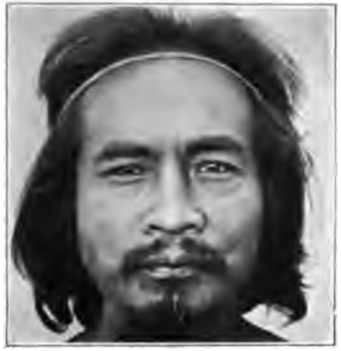


Fig. 1.

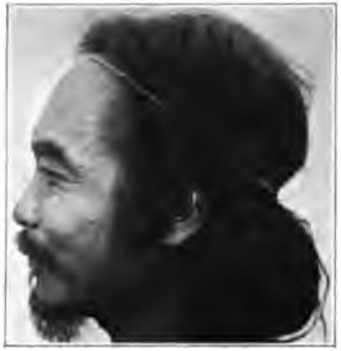


Fig. 2.

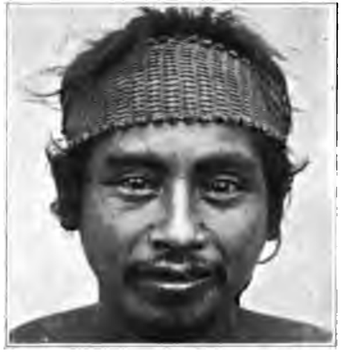
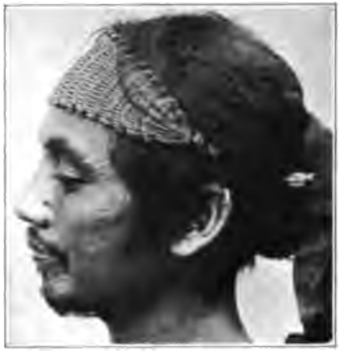


Fig. 3.



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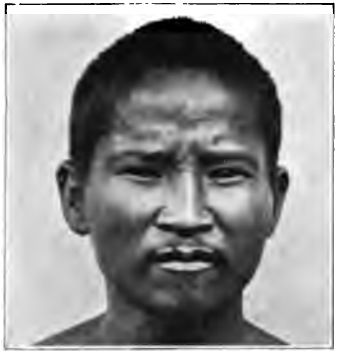

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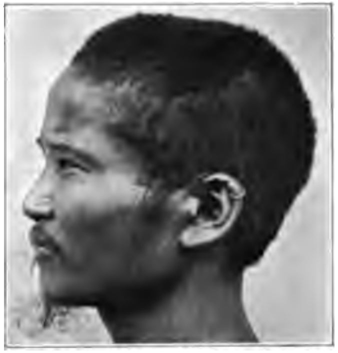

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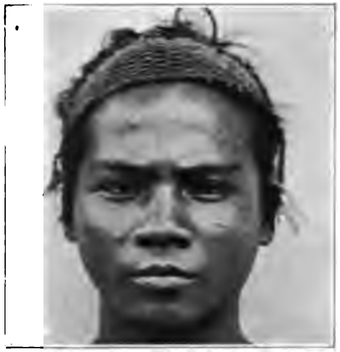


Fig. 7.

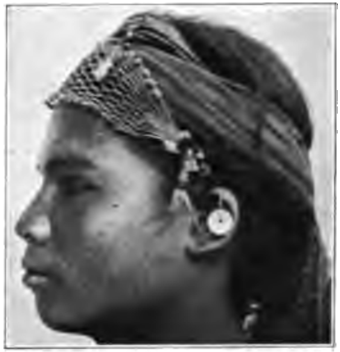


Fig. 8.

PLATE III. ILONGOTS. MUCH MODIFIED PRIMITIVE.

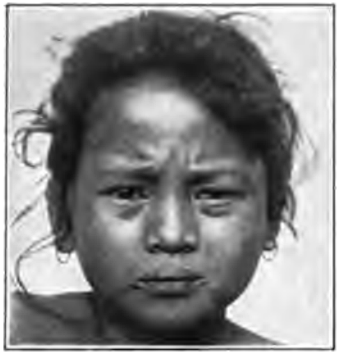


Fig. 1.

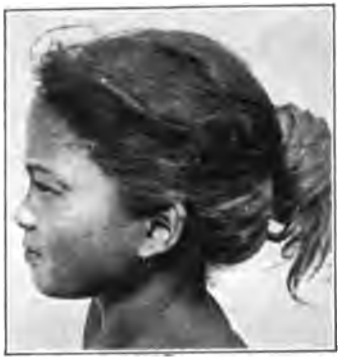
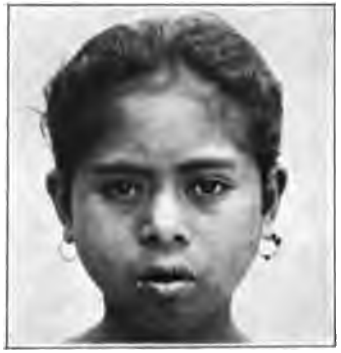


Fig. 2.



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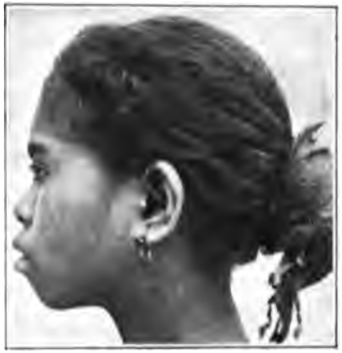


Fig. 4.

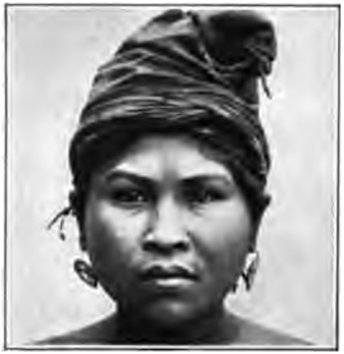
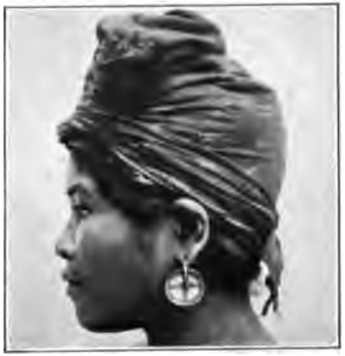


Fig. 5.



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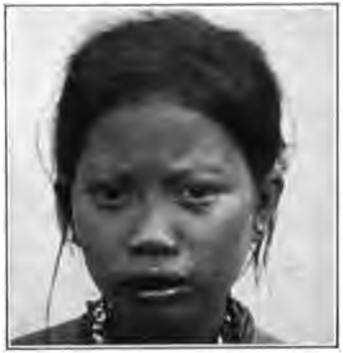

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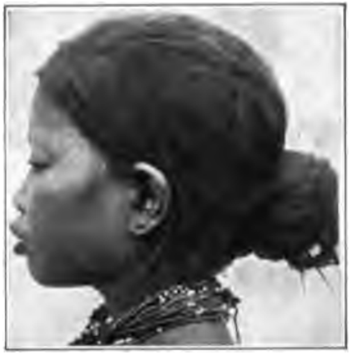


Fig. 8.

PLATE IV. ILONGOT AND MANGYAN WOMEN. PRIMITIVE.

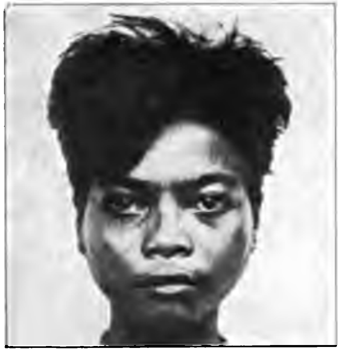


Fig. 1. Mañgyan man.

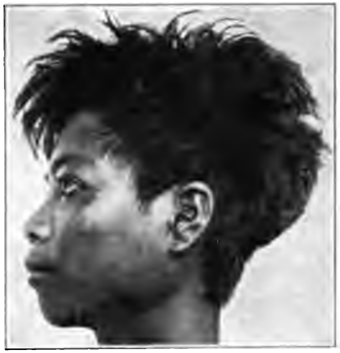


Fig. 2. Mañgyan man.

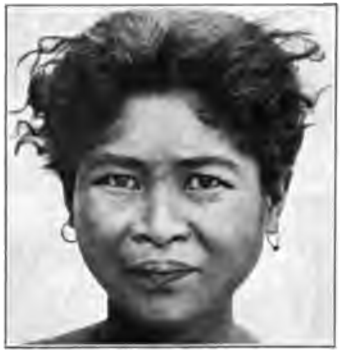


Fig. 3. Ilongot woman.

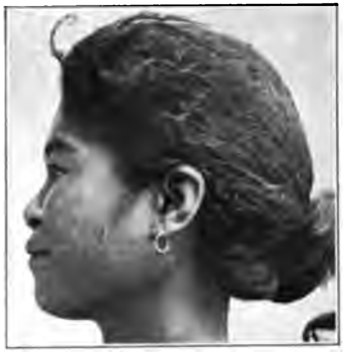


Fig. 4. Ilongot woman.

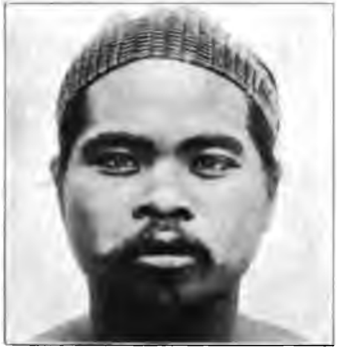


Fig. 5. Ilongot man.

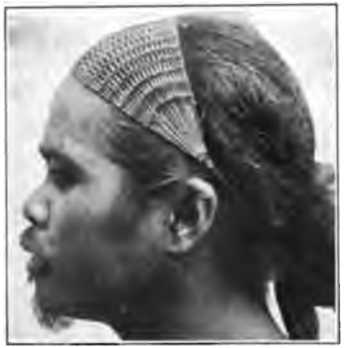


Fig. 6. Ilongot man.

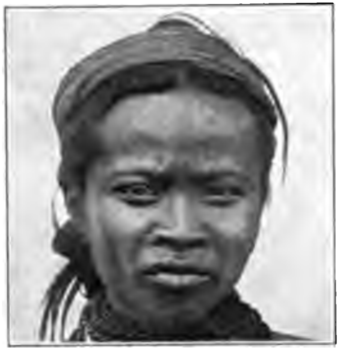


Fig. 7. Mañgyan man.

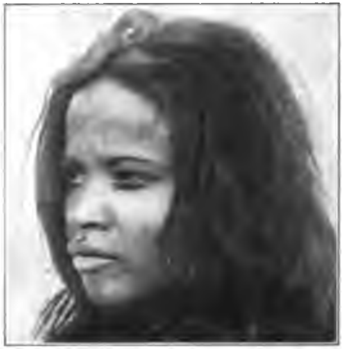


Fig. 8. Mañgyan man.

PLATE V. MODIFIED IBERIAN EARS, TYPE C.

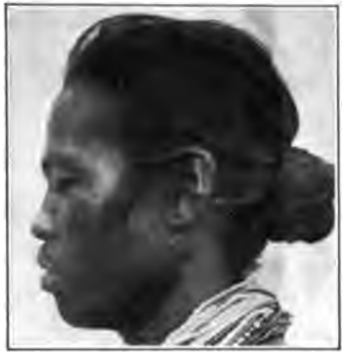


Fig. 1. Modified Iberian C.

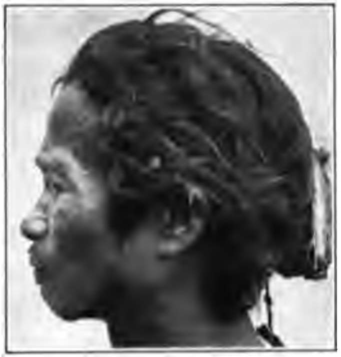


Fig. 2. Modified Iberian C.

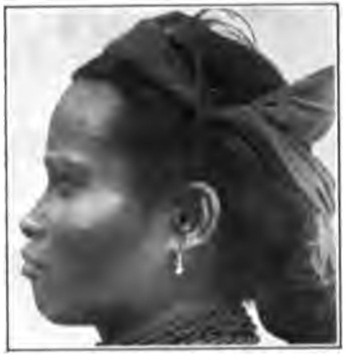


Fig. 3. Modified Primitive.

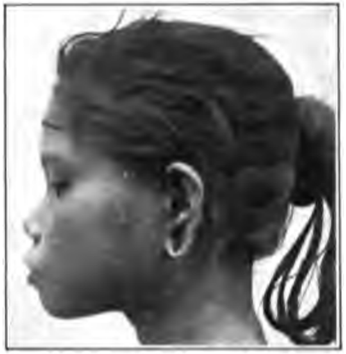


Fig. 4. Modified Primitive.

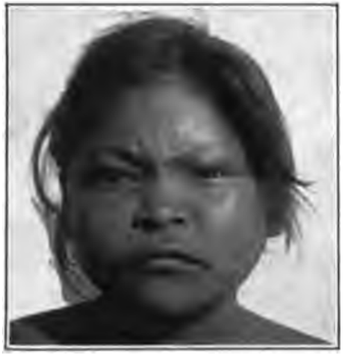


Fig. 5. Primitive.

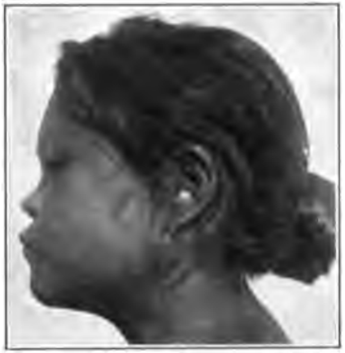


Fig. 6. Primitive.

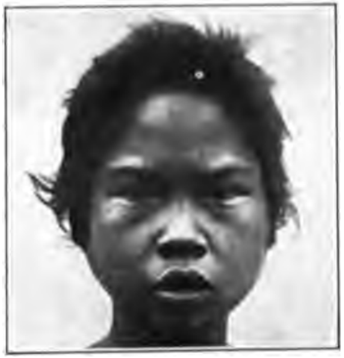


Fig. 7. Modified Primitive.

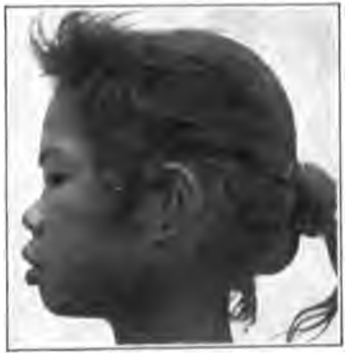


Fig. 8. Modified Primitive.

PLATE VI. TRANSITIONAL MANGYAN EAR FORMS. IBERIAN TO PRIMITIVE.

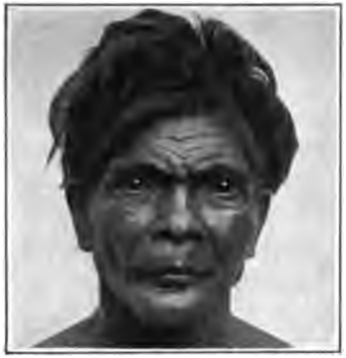


Fig. 1. Modified Primitive.

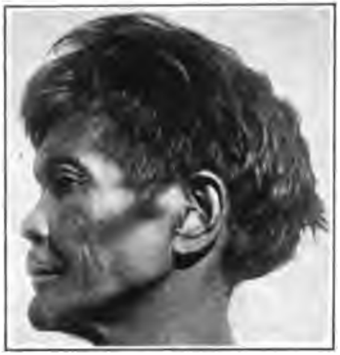


Fig. 2. Modified Primitive.

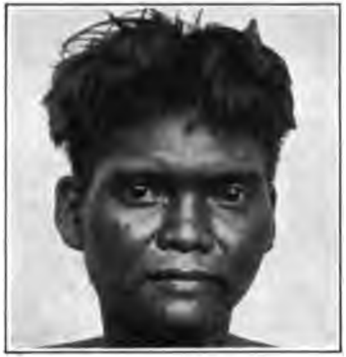


Fig. 3. Modified Iberian Alpine.

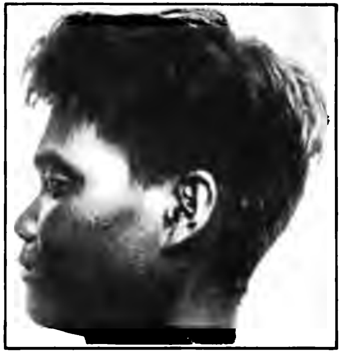


Fig. 4. Modified Iberian Alpine.

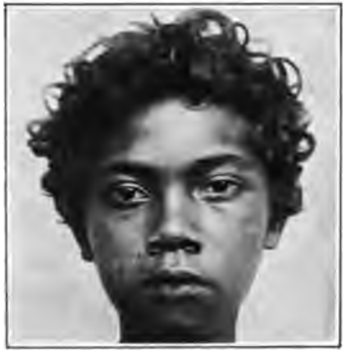


Fig. 5. Modified Primitive.

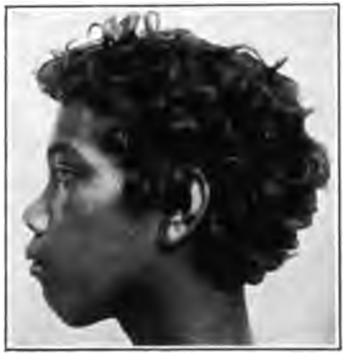


Fig. 6. Modified Primitive.

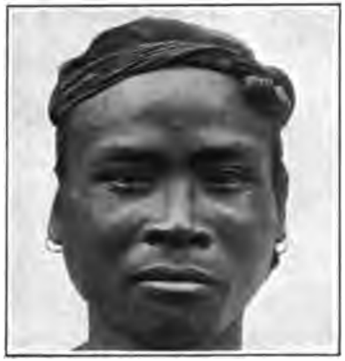


Fig. 7. Modified Australoid.

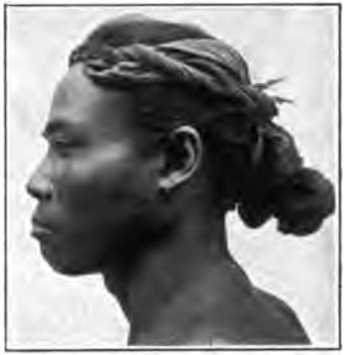


Fig. 8. Modified Australoid.

PLATE VII. MIXED MANGYANS.

87-5-11

1841-1922.

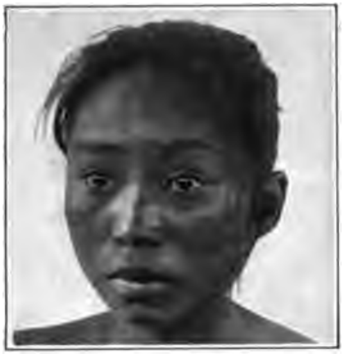


Fig. 1. Modified Iberian B.

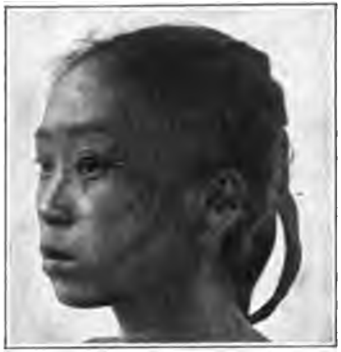


Fig. 2. Modified Iberian B.

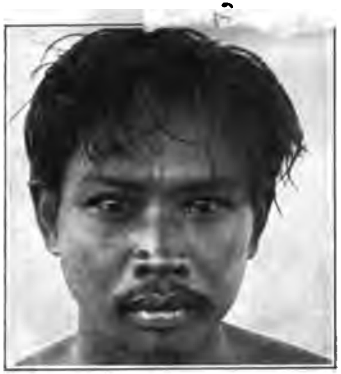


Fig. 3. Modified Primitive.

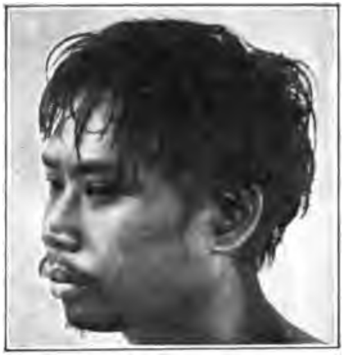


Fig. 4. Modified Primitive.

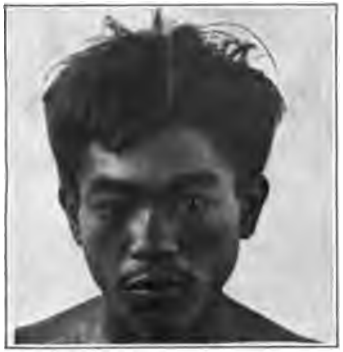


Fig. 5. Modified Primitive.

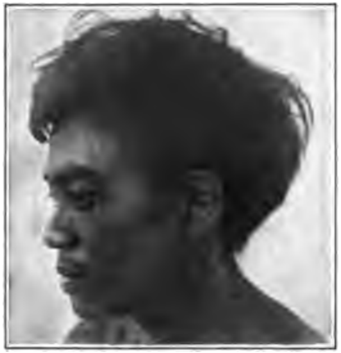


Fig. 6. Modified Primitive.

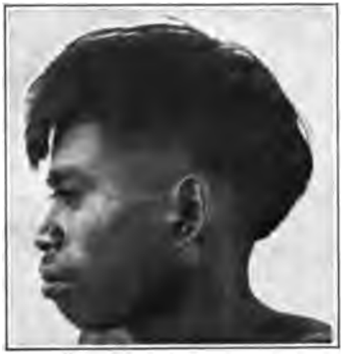


Fig. 7. Modified Iberian.

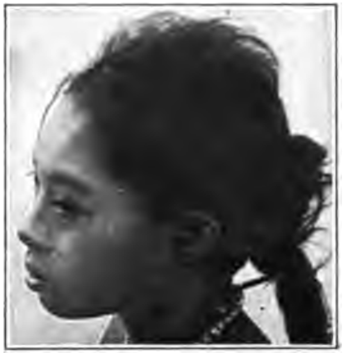


Fig. 8. Modified Primitive.

PLATE VIII. NEGRITIC MANGYANS.

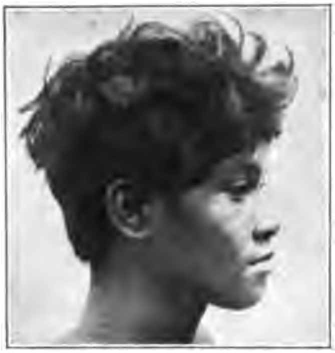


Fig. 1. Modified Primitive.

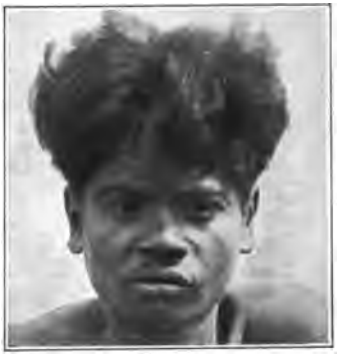


Fig. 2. Modified Primitive.

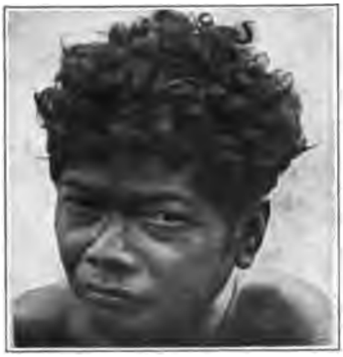


Fig. 3. Australoid.

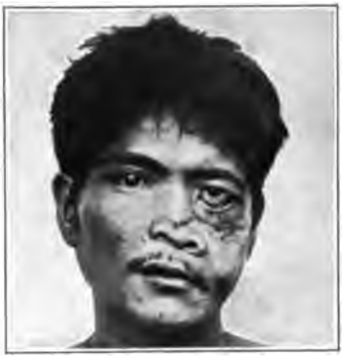


Fig. 4. Modified Iberian B.

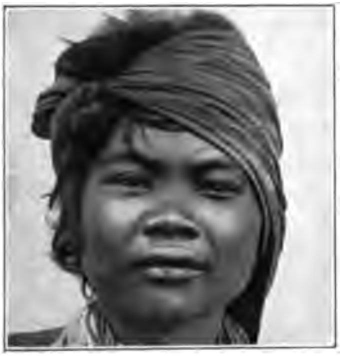


Fig. 5. Modified Primitive.

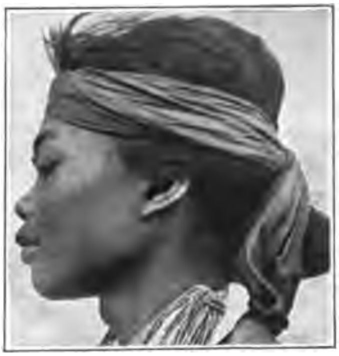


Fig. 6. Modified Primitive.

PLATE IX. MIXED MANGYANS.

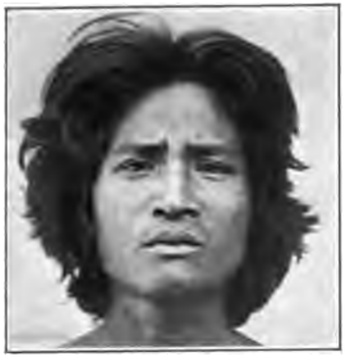


Fig. 1. Modified Alpine.

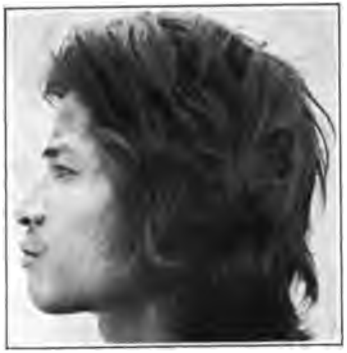


Fig. 2. Modified Alpine.

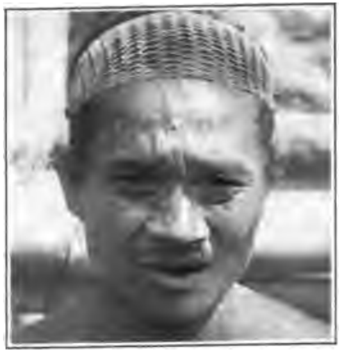


Fig. 3. Modified Alpine-Primitive.

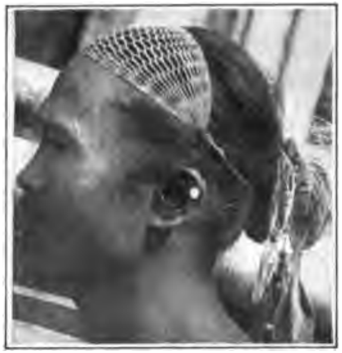


Fig. 4. Modified Alpine-Primitive.

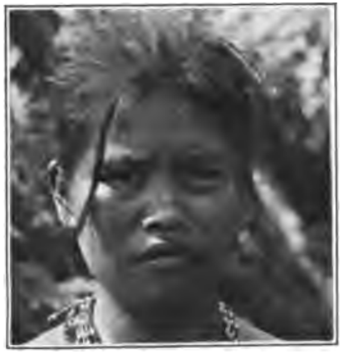


Fig. 5. Modified Primitive.

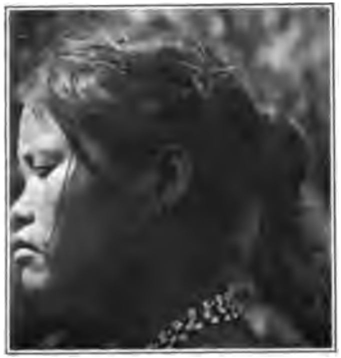


Fig. 6. Modified Primitive.

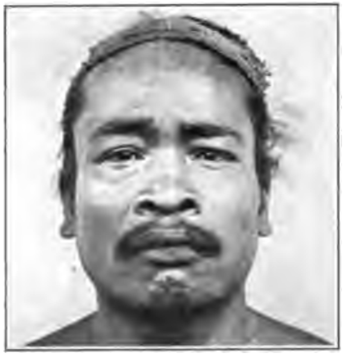


Fig. 7. Modified Primitive.

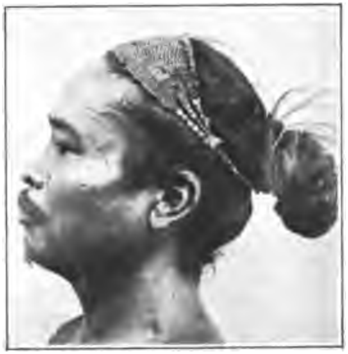


Fig. 8. Modified Primitive.

PLATE X. MODIFIED ALPINE AND PRIMITIVE ILONGOTS.

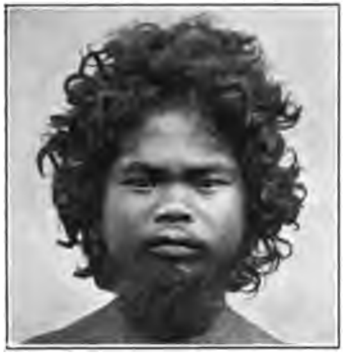


Fig. 1.

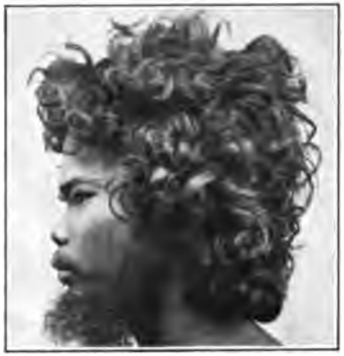


Fig. 2.

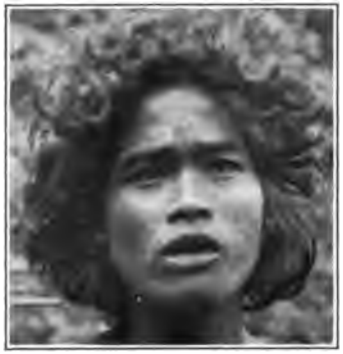


Fig. 3.

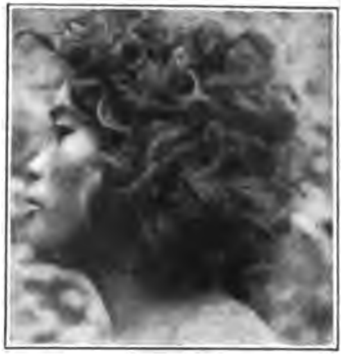


Fig. 4.

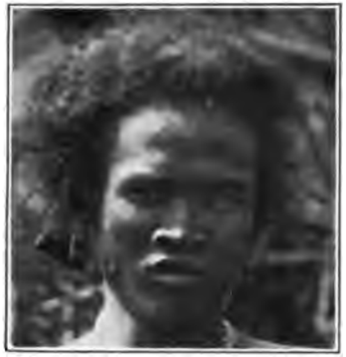


Fig. 5.

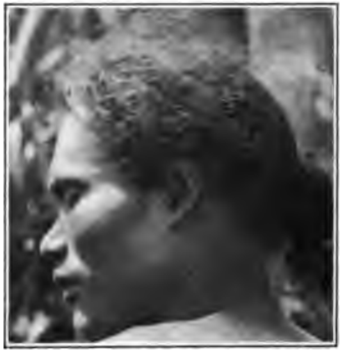


Fig. 6.

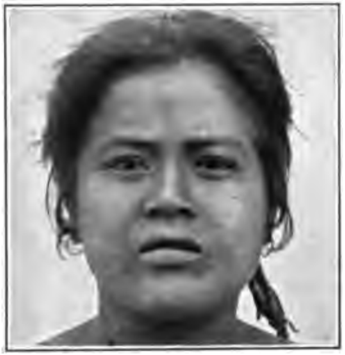


Fig. 7.

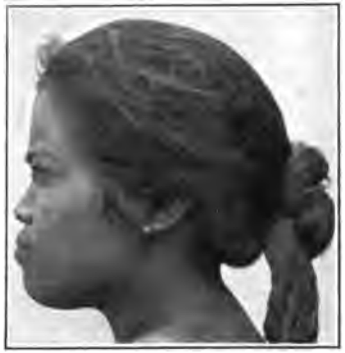


Fig. 8.

PLATE XI. CURLY- AND STRAIGHT-HAIRED ILONGOTS.

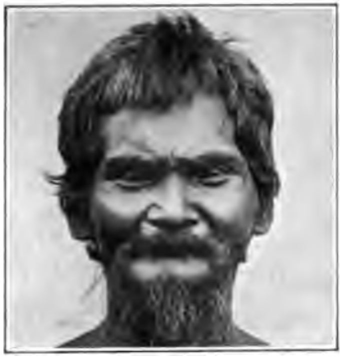


Fig. 1. Modified Iberian.

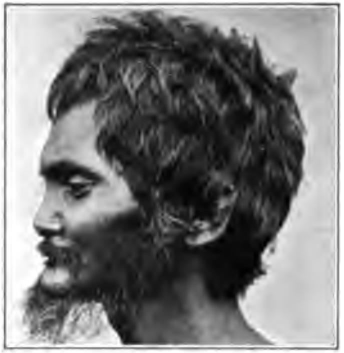


Fig. 2. Modified Iberian.

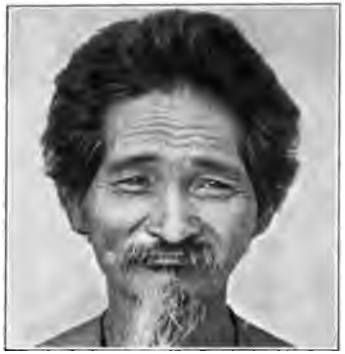


Fig. 3. Modified Iberian.

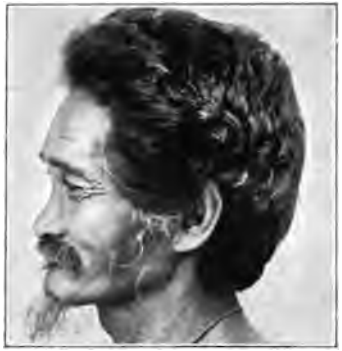


Fig. 4. Modified Iberian.

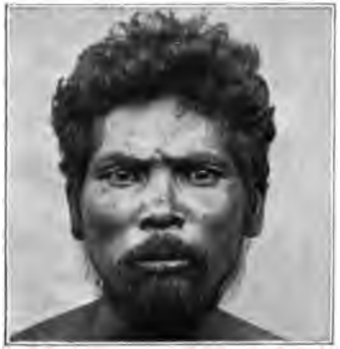


Fig. 5. Modified Primitive.

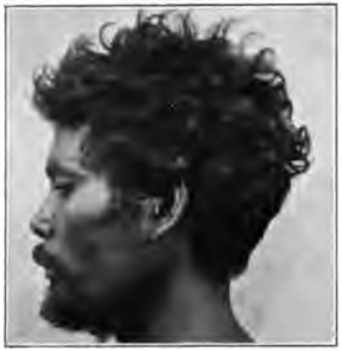


Fig. 6. Modified Primitive.

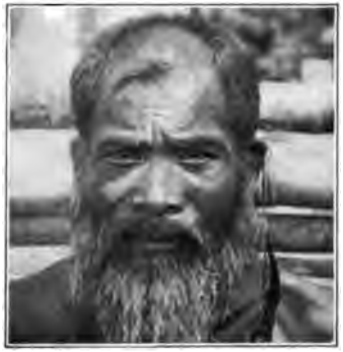


Fig. 7. Modified Primitive.

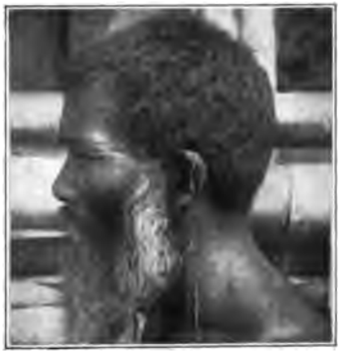


Fig. 8. Modified Primitive.

PLATE XII. HAIRY ILONGOTS.

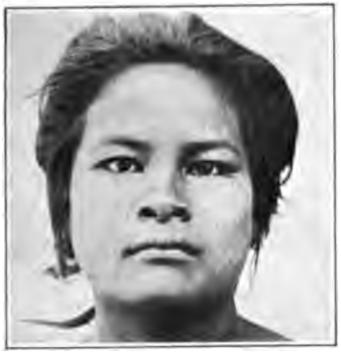


Fig. 1.

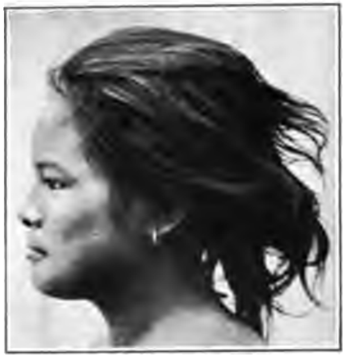


Fig. 2.

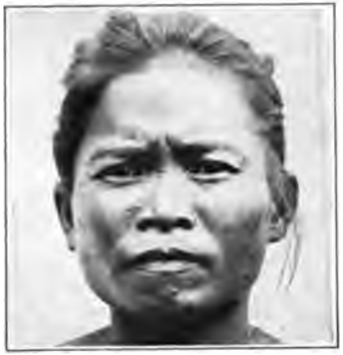


Fig. 3.

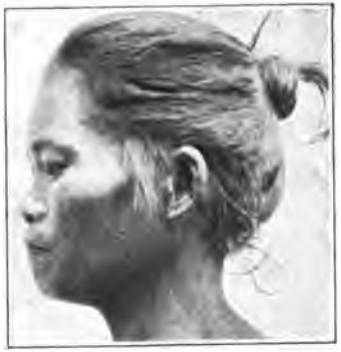


Fig. 4.

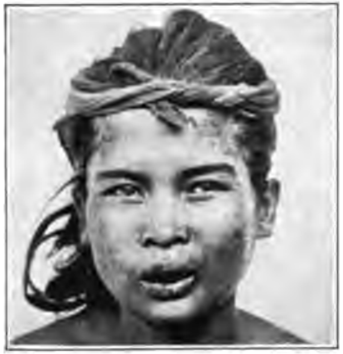


Fig. 5.

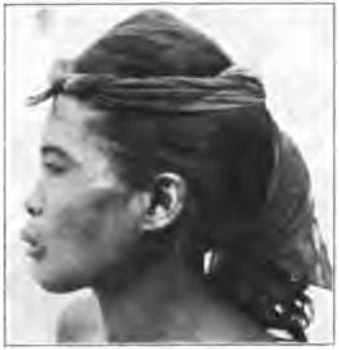


Fig. 6.

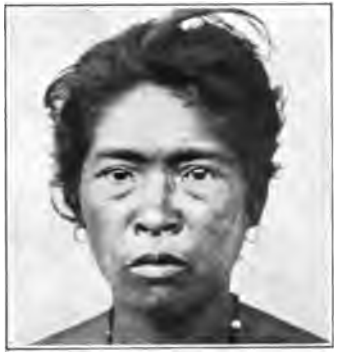


Fig. 7.

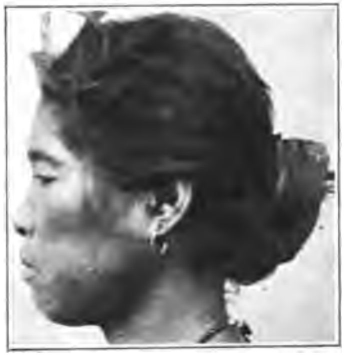


Fig. 8.

PLATE XIII. MODIFIED IBERIAN ILONGOT WOMEN.

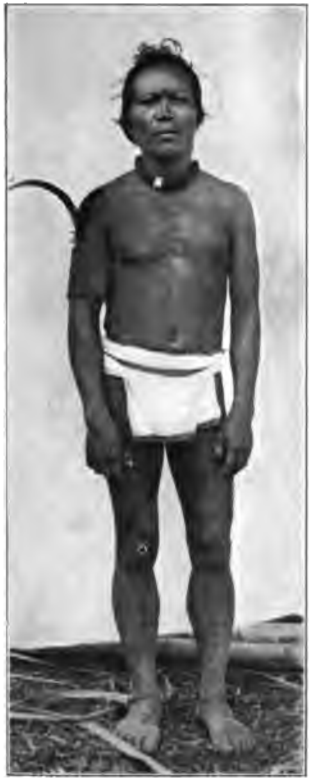
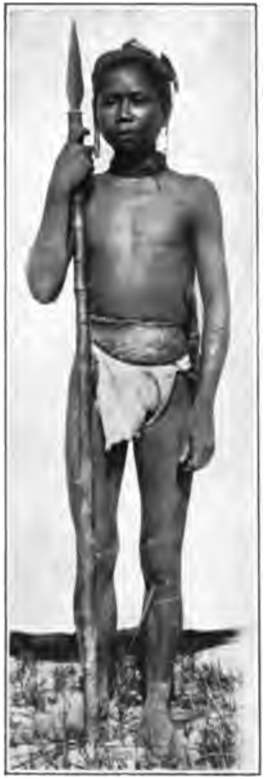


Fig. 1.



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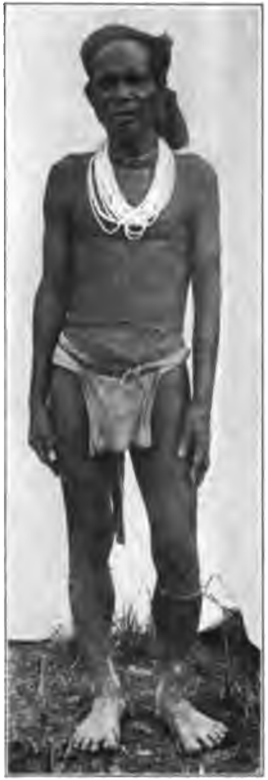

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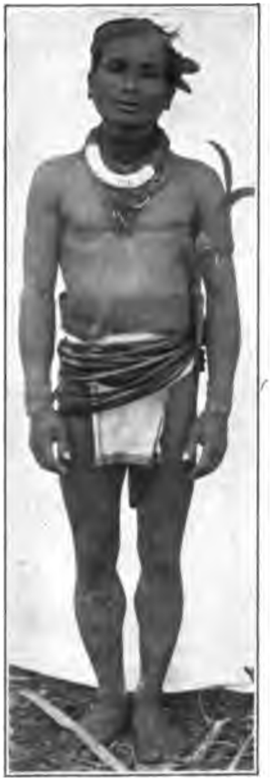
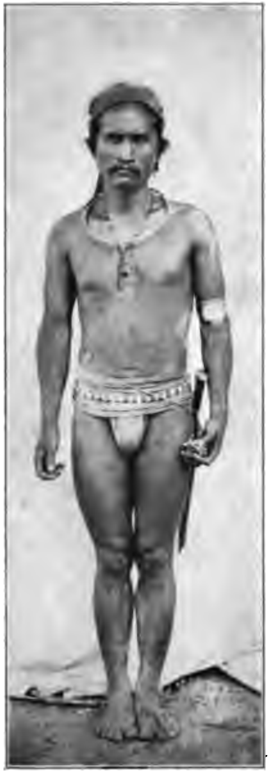


Fig. 4.

PLATE XIV. MANGYAN MEN. NOTE THE LONG LEGS.



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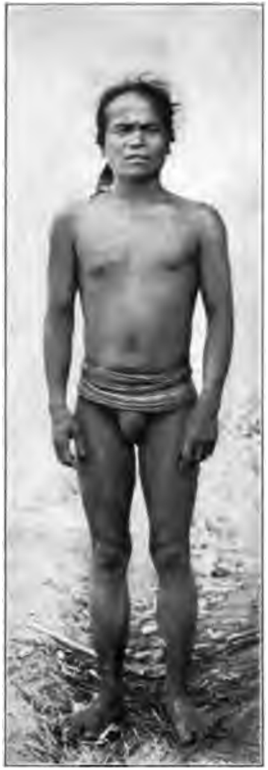

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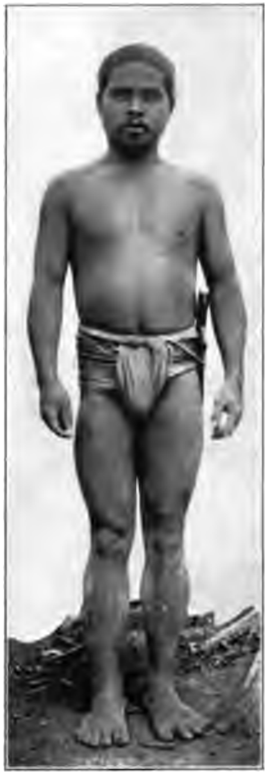

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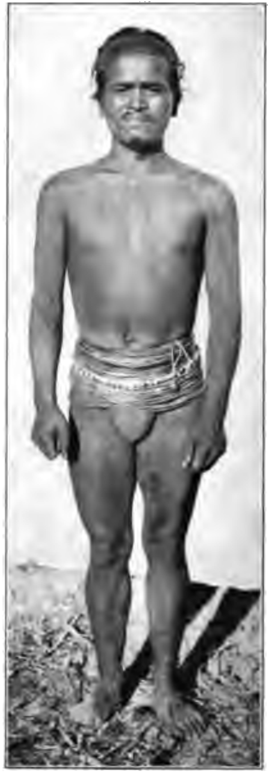
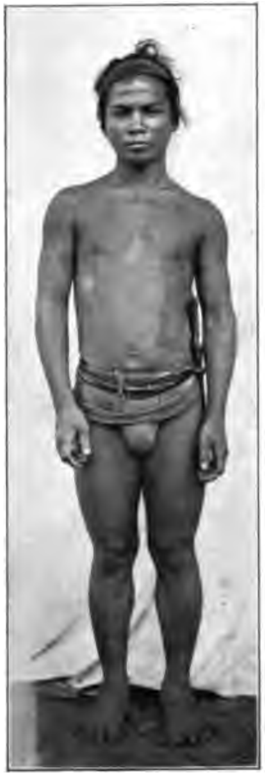


Fig. 4.

PLATE XV. ILONGOT MEN. NOTE THE SHORT LEGS.

Fig. 1.



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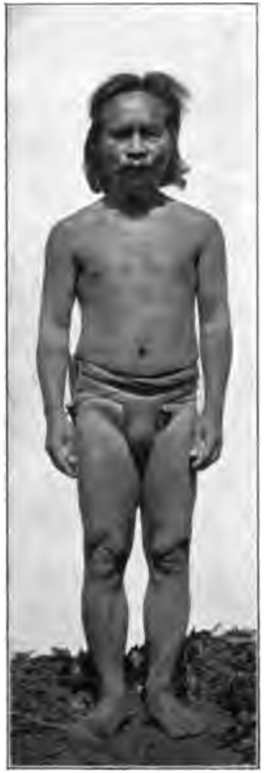


Fig. 3.

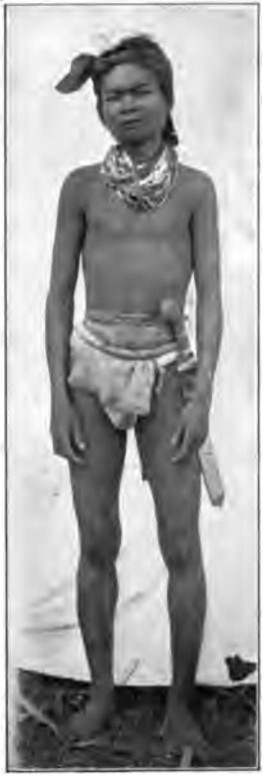


Fig. 4.

PLATE XVI. MANGYANS AND ILONGOTS.

Fig. 1.

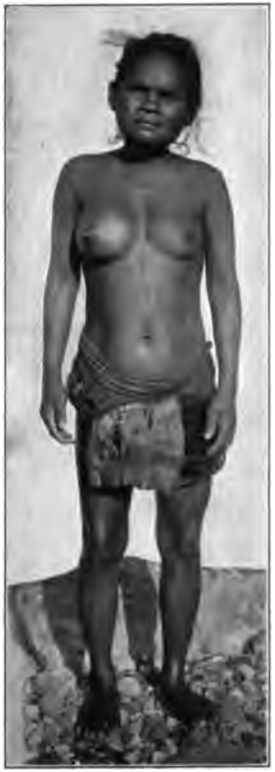


Fig. 2.

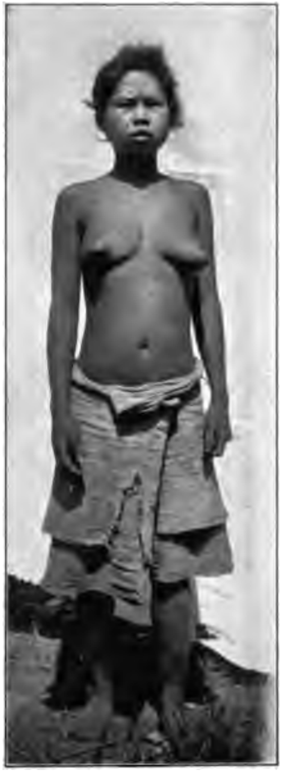


Fig. 3.

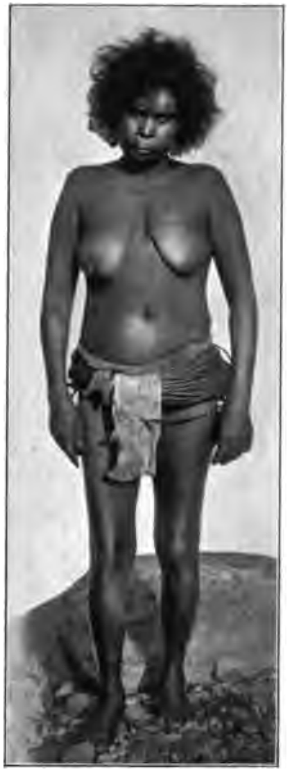
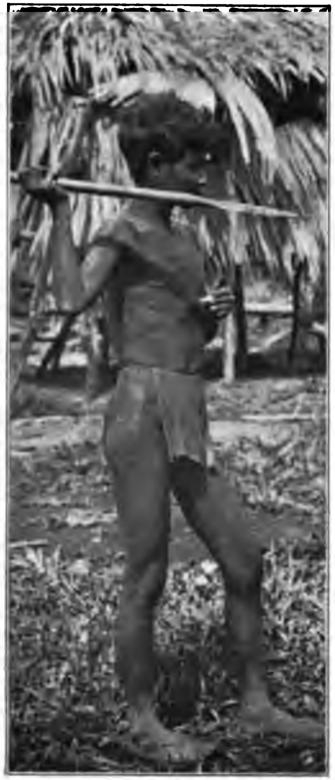


Fig. 4.

PLATE XVII. TYPICAL MANGYAN WOMEN.



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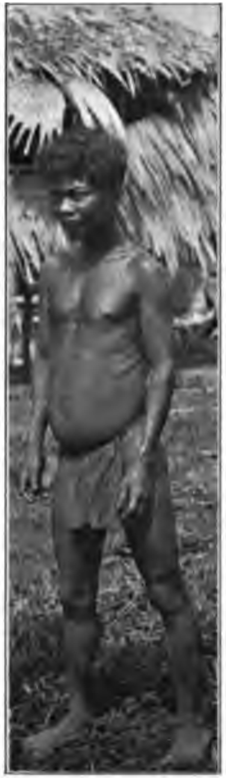

Fig. 2.

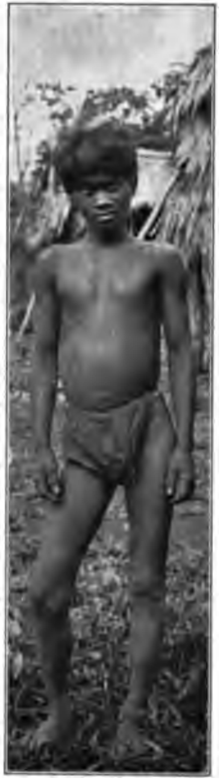

Fig. 3.

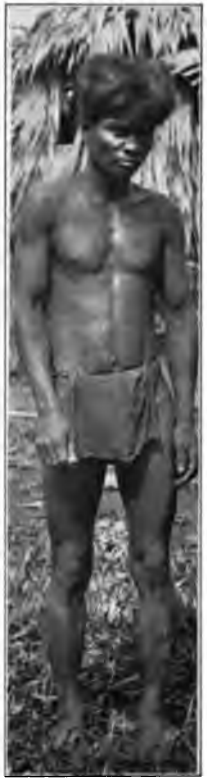

Fig. 4.

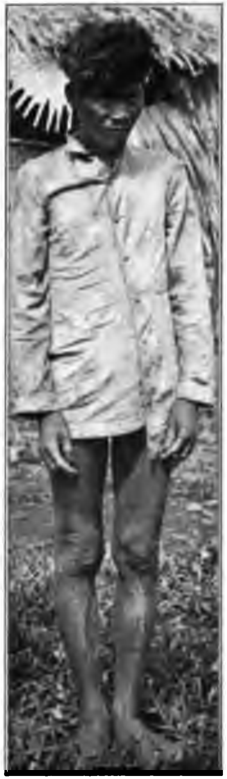

Fig. 5.

PLATE XVIII. MANGYANS OF BANGANAY. MIXED NEGRITOS OF THE AUSTRALOID TYPE.

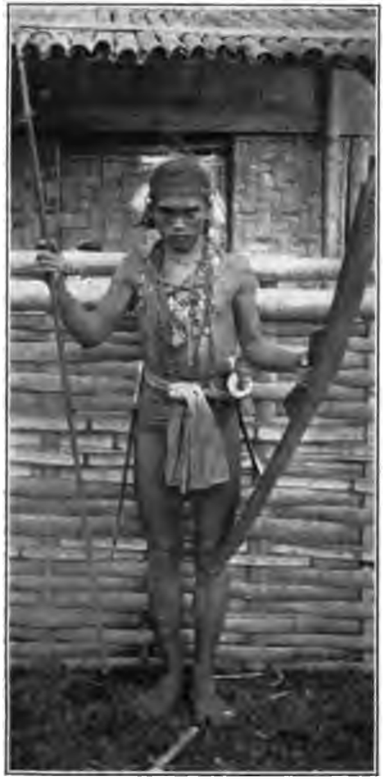

Fig. 1.

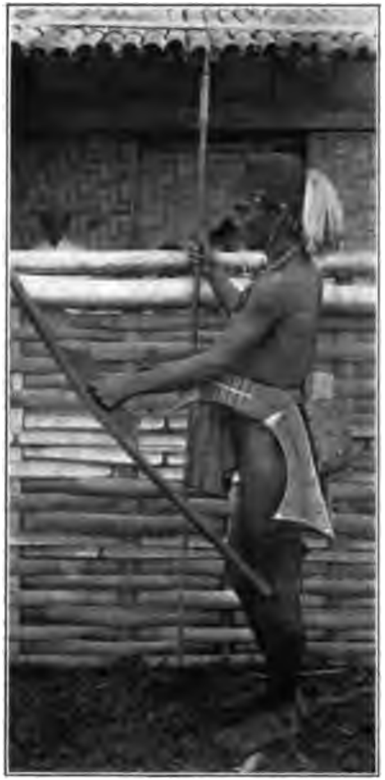

Fig. 2.

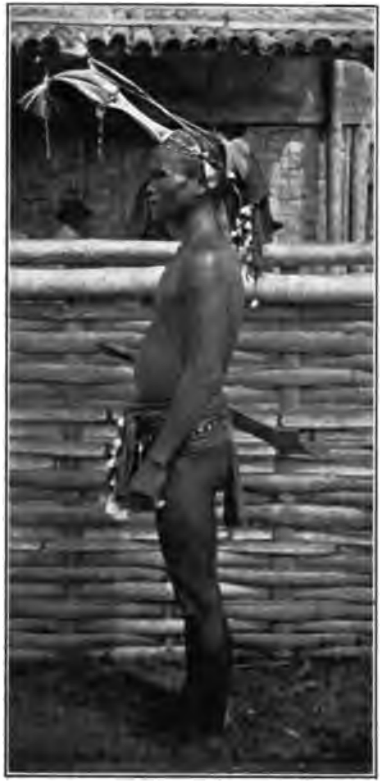

Fig. 3.

PLATE XIX. TYPICAL ILONGOTS WITH DRESS SUITS AND DECORATIONS.

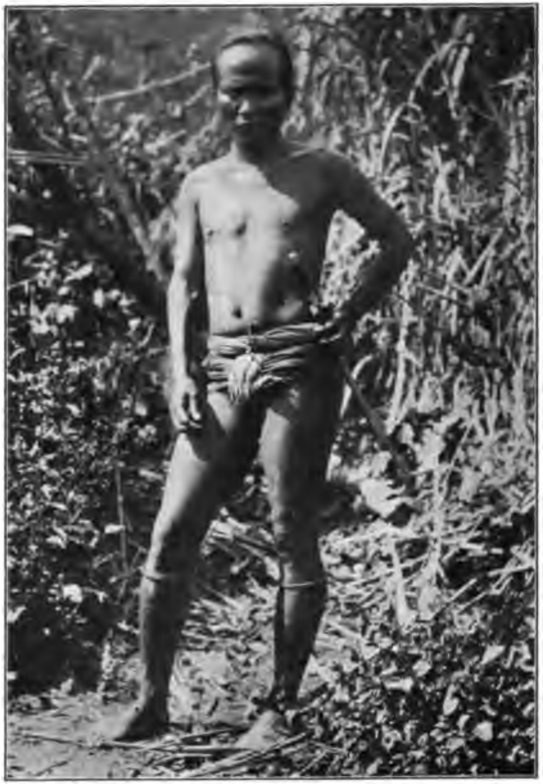

Fig. 1.

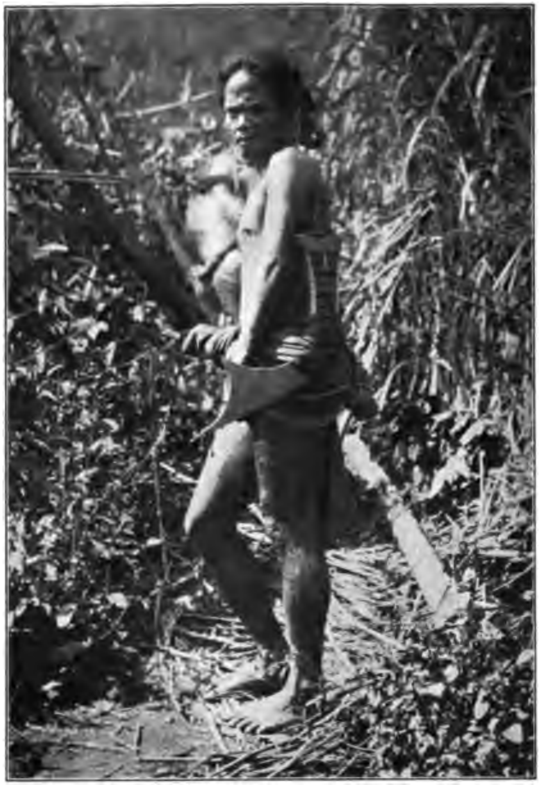

Fig. 2.

PLATE XX. TYPICAL ILONGOTS.

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July, 1913

THE CEPHALIC NERVES: SUGGESTIONS

ROBERT BENNETT BEAN

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THREE FIGURES

The BNA term 'cerebral' as applied to the nerves of the head is a misnomer. There are only four cerebral nerves proper, although the nerve of taste may have cerebral terminals. Hardesty, in the anatomy of Morris, returned to the use of the old term 'cranial' in preference to 'cerebral' and rightly so, because the nerves distributed in the head do pass through openings in the base of the skull, and but four of them are attached to the cerebrum.

Furthermore, the cranial nerves need a reclassification. No author or publisher of a text-book of anatomy has yet been brave enough to replace the twelve pairs of cranial nerves with the nerves as they really exist. The time is propitious for some alteration because of the gross errors and apparent complexity that exist in an attempt to conform recent discoveries with old fashioned notions.

For instance, there are not two olfactory nerves but about forty, the olfactory bulb and tract being not a nerve but an outgrowth of the brain. Likewise, the optic nerve is not a nerve but another outgrowth of the brain: There is a retina which is a modified cerebral cortex, an association tract and a decussation, but no nerve proper. The first and second pairs of cranial nerves should therefore be described with the olfactory apparatus and the optic apparatus. The tenth and eleventh cranial nerves should not be considered with the nerves of the head, because they are distributed to the neck, shoulder and trunk, and form an intermediate stage between the cervical spinal nerves and cranial (why not cephalic?) nerves. Omitting these four pairs of nerves there remain but eight of the usually so-named cranial nerves. However, if only one cranial nerve be lost the classic twelve is broken and all indication by numerals may as well be discarded.

I therefore propose an alteration in the terminology of the present so-called cranial nerves in the following manner:

1. Call the nerves distributed in the head the *cephalic* instead of the cranial or cerebral nerves. The head includes the cranium and face, with the orbital, nasal and buccal cavities as a part of the latter.

2. Omit the olfactory and optic nerves and describe them under their proper apparatuses.

3. Omit the pneumogastric and spinal accessory nerves from the cephalic group because they belong to the spinal cord type, or may be considered as transitory nerves between the spinal cord and brain, and they are not distributed to the head but to the neck, shoulders and trunk.

4. Add three nerves to the cephalic group.

a. Add the motor root of the trigeminals, which is as much a separate nerve as the facial, the two supplying motion to the mandible and face, as motor reciprocal to the trigeminal which supplies sensation to the teeth and face. The name of the motor root of the trigeminal should be the masticator nerve (n. masticatorius), as given in the BNA, because it supplies the muscles of mastication.

b. Add the sensory part of the facial, including the intermediate nerve of Wrisberg, the geniculate ganglion containing the cells of origin of this nerve, and the chorda tympani, with its distribution in the tongue and palate. Call this nerve the glossopalatine nerve (n. glossopalatinus), as suggested by Hardesty. The work of Streeter, Cushing, Sheldon and others demonstrates that this nerve is only a segregated portion of the glosso-pharyngeal nerve in its ontogeny and phylogeny, as well as in its central and peripheral terminations, but its roundabout course necessitates a separate name.

c. Add the nerve of the semicircular canals, separating it from the nerve of the cochlea. Retain the name acoustic or auditory for the latter and give the former separately the name it bears at present, vestibular nerve.

5. Finally, omit the sympathetic ganglia of the head, especially the ciliary, sphenopalatine, otic and submaxillary, from the description of the cephalic nerves, and constitute them as a ganglionated cephalic plexus, including the sympathetic part of the geniculate, petrous and jugular ganglia, the prolongation upward of the cervical sympathetic system. This will be considered separately at the end of this study.

The nerves as rearranged may be enumerated as the cephalic nerves:

NAME	DISTRIBUTION	NATURE
Oculo-motor	eye muscle	motor
Trochlear or pathetic		motor
Abducens		motor
Trigeminal or trifacial	face	sensory
Masticator		motor
Facial		motor
Auditory or acoustic	internal ear	sensory
Vestibular		sensory
Glossopharyngeal	tongue, palate, etc.	sensory (mixed)
Glossopalatine		sensory (mixed)
Hypoglossal		motor

This is a more rational arrangement than that of the twelve cranial nerves, if only the grouping of the nerves of like distribution is considered and when it is kept in mind that the origin and central connections, course and distribution of each nerve is distinct, their individuality is apparent.

It may be well to give descriptions of the newly constituted nerves, the masticator nerve, the vestibular nerve and the glossopalatine nerve, although the masticator and vestibular nerves are so well known under the names of the motor root of the trigeminal, and the vestibular part of the acoustic, respectively, that only the glossopalatine nerve will be described in detail. Diagrams are given to illustrate the course and distribution of the masticator and glossopalatine nerves, and the ganglionated cephalic plexus and its connections. (figs. 1, 2 and 3).

The glossopalatine nerve

This nerve consists of four parts which have been recognized as parts of one nerve but not so described in the text-books. The four parts are the pars intermedia or intermediate nerve of Wrisberg, the geniculate ganglion, the chorda tympani and the palatine portion of the nerve. The nerve is apparently an aberrant part of the glossopharyngeal nerve. Its cells of origin are located in the geniculate ganglion, the peripheral processes

ABBREVIATIONS

a.d.t.n., anterior deep temporal nerve
a.t.n., auricular temporal nerve
b.n., buccinator nerve
c.p., carotid plexus
c.a., carotid artery
c.t., chorda tympani
c.b., communicating branch to middle cervical sympathetic ganglion
c.g., ciliary ganglion
c.t.n., caroticotympanic nerve (small deep petrosal)
c.c.p., carotid and cavernous plexuses
c.n., carotid nerve
e.p.n., external pterygoid nerve
e.c.a., external carotid artery
e.s.p.n., external superficial petrosal nerve
f.n., facial nerve
f.a., facial artery
f.n.f., facial nerve fibers
G.g., Gasserian ganglion
g.n., glossopharyngeal nerve
g.p. of g.g., glossopalatine portion of geniculate ganglion
gen.g., geniculate ganglion
g.s.p.n., great superficial petrosal nerve
g.d.p.n., great deep petrosal nerve
g.p.n., glossopalatine nerve
g.r., geniculotympanic ramus
i.c.t.n., inferior carotico tympanic nerve
i.c.n., internal carotid nerve
i.p.n., internal pterygoid nerve
i.m.a., internal maxillary artery
i.a.n., inferior alveolar nerve
j.n., jugular nerve
j.g., jugular ganglion
l.n., lingual nerve
mas.n., masseter nerve
my.n., mylohyoid nerve
m.m.a., middle meningeal artery
max.n., maxillary nerve
m.m., mandibular nerve
mas.n., masticator nerve
n. of p.c., nerve of the pterygoid canal (Vidian)
n.p., nodosal plexus
o.g., otic ganglion
oc.n., oculomotor nerve
op.n., ophthalmic nerve
p.i., pars intermedia
p.d.t.n., posterior deep temporal nerve
p.n., petrosal nerve
p.g., petrous ganglion
p.p., of g.n., palatine portion of glossopalatine nerve
s.g., sphenopalatine ganglion
sub.g., submaxillary ganglion
s.c.s.g., superior cervical sympathetic ganglion
s.s.p.n., small superficial petrosal nerve
s.g., sphenopalatine ganglion
t.n., tympanopetrosal nerve
t.p., tympanic plexus
tym.n., tympanic nerve (Jacobson's)
tri.n., trigeminal nerve
v.n., vagus nerve

of which end in the anterior two-thirds of the tongue and the soft palate, and the central processes of which terminate about cells superior to the nucleus of termination of the glossopharyngeal nerve in the medulla.

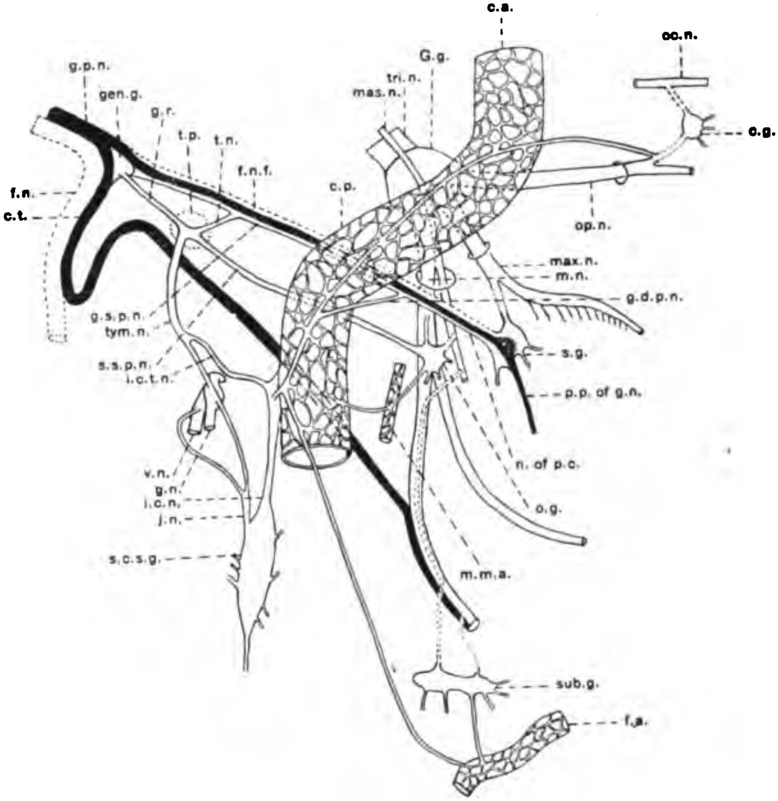

Fig. 1 Diagram showing the glossopalatine nerve and the ganglionated cephalic plexus. Each ganglion has three roots; the motor root is in broken lines, the sensory is in dotted lines and the sympathetic is in solid lines. Mesial view, left side.

The geniculate ganglion is embedded in the anterior border of the great bend of the facial nerve behind the hiatus Fallopii. It is somewhat triangular in form and at its three angles three nerves are found. Its external angle has the chorda tympani attached, its anterior angle is connected with the great superficial petrosal nerve, and its superior angle has the root of the inter-

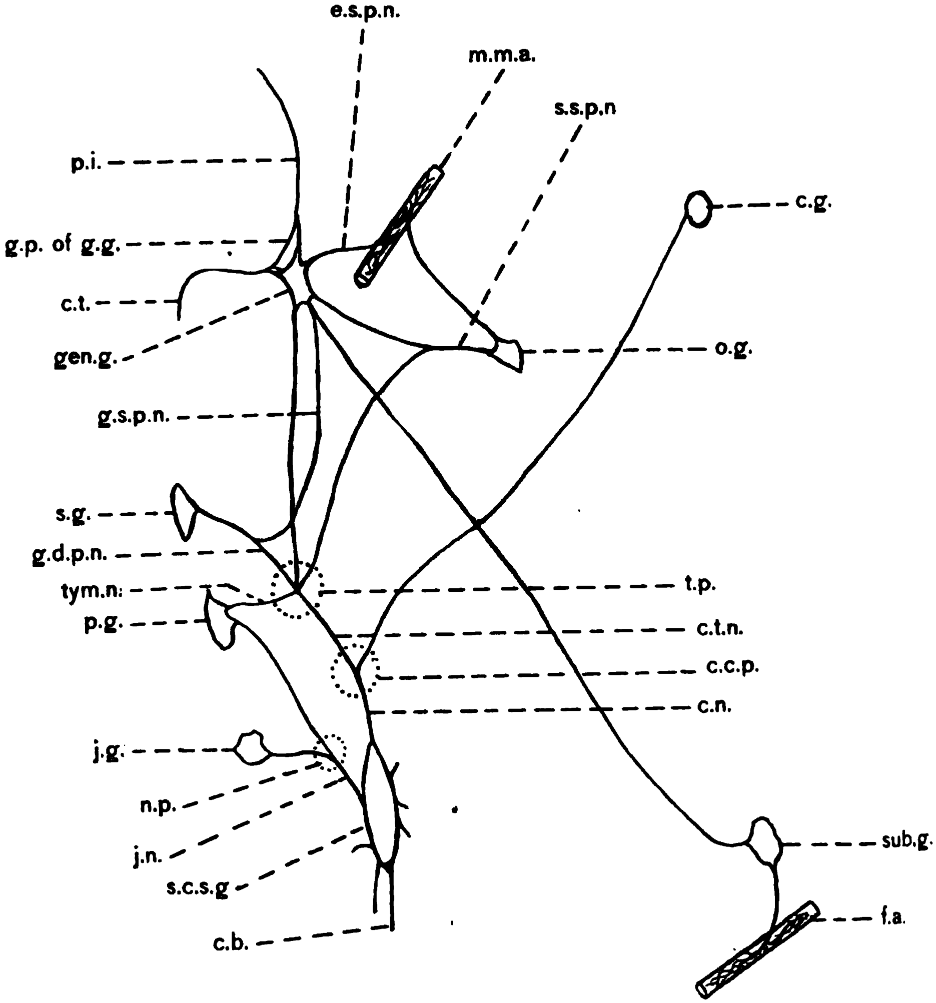

Fig. 2 Scheme to represent the continuity of the sympathetic connections of the cephalic ganglia (ganglionated cephalic plexus).

mediate nerve proper. A part of the geniculate ganglion belongs to the sympathetic system and will be described below with the ganglionated cephalic plexus.

The fibers of the intermediate nerve concerned in the glossopalatine nerve pass from the geniculate ganglion in the facial canal (aqueduct of Fallopius) inside the sheath of the facial nerve, which it leaves as it passes inward through the internal auditory meatus to turn slightly downward in the posterior fossa of the cranium. It enters the medulla immediately below the pons between the facial and auditory nerves, passes through the reticular formation inward and backward to terminate in the group of cells superior to the nucleus of termination of the glossopharyngeal nerve. In the internal auditory meatus the nerve gives two delicate filaments to the vestibular nerve. The intermediate nerve contains a few motor fibers probably acquired while it is in the sheath of the facial nerve. It also may contain secretory fibers from the medulla whose impulses reach via sympathetic neurones the glands and mucous membrane of the salivary apparatus.

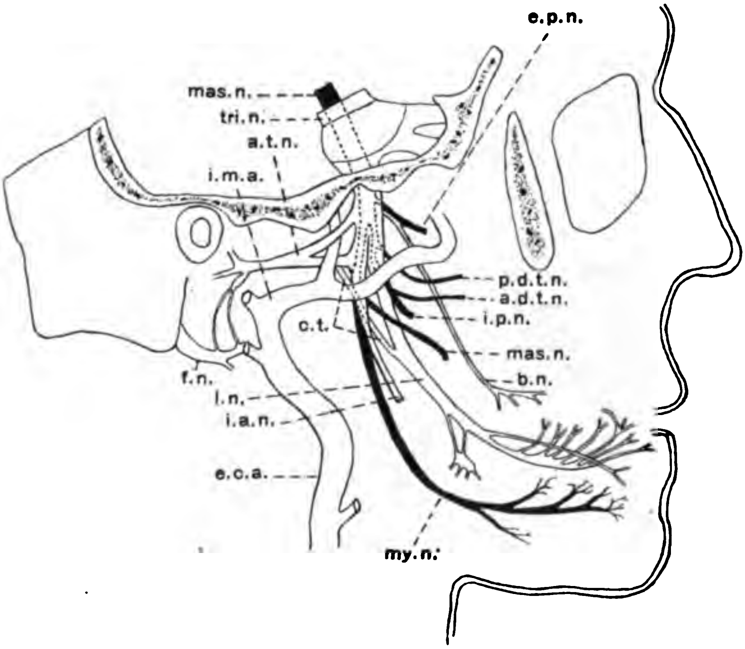

Fig. 3 Schematic representation of the masticator nerve (in black); modified from Spalteholz. Lateral view, right side.

The chorda tympani is so well known it need not be described. Other sensory fibers of the glosso-palatine nerve besides those of the chorda tympani rise in the geniculate ganglion and pass through the great superficial petrosal nerve and the spheno-palatine ganglion to the soft palate where they are probably connected with the peripheral taste organs found there, as well as serving as fibers of general sensibility for the palate.

Enough has been said to indicate the most essential changes to bring the nerves of the head up to date. There is one other change, a change in the hypoglossal nerve. The ansa hypoglossi or loop of the hypoglossal is not a part of this nerve and should not be included with it but instead should be described with the cervical plexus of which it is a part. The name ansa hypoglossi should be discarded and in its place the name ansa cervicalis substituted. Likewise the descendens hypoglossi and the communicans hypglossi should be altered to the descendens cervicalis and the communicans cervicalis.

Whether the suggestions here given be followed or not there can be no doubt that such changes would clarify and simplify the cephalic nerves. The removal of the ganglia and their connections from the facial, trigeminal and glosso-pharyngeal nerves, and so forth, simplifies these nerves, and the segregation of the masticator, vestibular and glosso-palatine nerves further simplifies the nerves with which they are usually described.

The ganglionated cephalic plexus (figs. 1–2)

The ganglia of the head receive and distribute three classes of fibers, motor, sensory and sympathetic. They do not belong to any one nerve or set of nerves, although they all have sympathetic connections and may be considered as the prolongation upward of the cervical sympathetic ganglia. They correspond both structurally and developmentally with the sympathetic ganglia, except those parts of the geniculate, petrous, and jugular ganglia which represent the dorsal root ganglia, or ganglia of origin of the sensory portions of the glossopalatine, glossopharyngeal, and pneumogastric nerves respectively. Some of these ganglia of the head are vagrant ganglia which separated from the embryonal semilunar or Gasserian ganglion at an early period of development—just as the sympathetic ganglia of the neck and trunk separated from the embryonal spinal ganglia.

These ganglia of the head with their connections may be conveniently grouped together as *the ganglionated cephalic plexus*, and may be said to consist of the ciliary, the sphenopalatine or Meckel's ganglion, the otic, the submaxillary, and a part of the geniculate, of the petrous and of the jugular ganglion.

Each ganglion may be said to possess a motor root, a sensory root, and a sympahetic root, and the ganglia act as relays and points of dispersal for these three sets of fibers. Motor impulses go to the eyeball, the palate, the middle ear and the pharynx; sensory impulses come from the same regions and from the lining of the mouth; and secretory fibers are distributed to the lachrymal glands, to the mucous membrane of the nose and mouth, pharynx and palate, to the parotid glands, and to the submaxillary and sublingual glands.

The superior cervical sympathetic ganglion gives off two large branches which pass upward to communicate with the ganglionated cephalic plexus. One of these, the carotid nerve, is the direct continuation upward of the gangliated cord, and through its branches, the caroticotympanic and the deep petrosal nerves, as well as through the plexuses derived from it, this nerve communicates with practically all the ganglia of the head. Another nerve from the superior cervical sympathetic ganglion, the jugular nerve, passes directly to the ganglia of the pneumogastric and glossopharyngeal nerves, through the nodosal plexus to the jugular ganglion, and directly to the petrous ganglion.

It may be well to describe each ganglion with its roots of origin, and its branches of distribution, in order to obtain a clear insight into the composition of the ganglionated cephalic plexus. Whereas the three roots will be described in the terminology of gross anatomy, it is realized that in their microscopic construction the roots of the sympathetic portions of the jugular, petrous and geniculate ganglia especially, may be of varying significance. Very few fibers of the sensory root of a sympathetic ganglion actually terminate within the ganglion, about its cells, and probably none except the few which terminate in its capsule, and in which arise general sensations from the ganglion to the central system. A motor root of a sympathetic ganglion may consist of two varieties of fibers; those which arise in the motor nuclei (of origin) in the central system and terminate about cells within the sympathetic ganglion (splanchnic efferent fibers) and, second, those which have the same origin and pass through the ganglion uninterrupted to their termination upon striated muscle (somatic efferent fibers), or pass through and go as splanchnic efferent fibers to other sympathetic ganglia. A sympathetic root of a ganglion may consist of two or even three varieties of fibers: (1) those which arise from cells in other sympathetic ganglia and terminate about cells in the ganglion in question, which cells in turn contribute fibers to its branches of distribution; (2) fibers arising in other sympathetic ganglia which pass through the ganglion uninterrupted, and out with its branches of distribution; and (3), in case of the mixed ganglia of cephalic and spinal nerves especially, fibers arising in sympathetic ganglia which enter the ganglion in question and terminate about cell bodies of the dorsal root ganglion type, that is, cell bodies giving origin to ordinary cerebro-spinal sensory fibers, which are thus enabled to carry into the central system sensory impulses arising in the sympathetic distribution, as well as sensations arising in the cerebro-spinal peripheral terminations. The present knowledge of the minute construction of the ganglia of the ganglionated cephalic plexus and the origin of the fibers related to them in the plexus renders it impossible to use a terminology in describing them based upon their construction.

The jugular ganglion

This ganglion lies on the trunk of the vagus nerve in the jugular foramen. It receives its motor and sensory roots from the vagus nerve and its sympathetic root from the superior cervical sympathetic ganglion through the nodosal plexus immediately inferior to it.

Its chief nerve of distribution is the auricular branch of the vagus, or nerve of Arnold, which leaves the jugular ganglion in the jugular foramen. It receives a branch from the petrous ganglion, enters the mastoid canaliculus in which it receives a communication from the facial nerve or merely lies in contact with it as far as the stylomastoid foramen, where it leaves the temporal bone. It may pass through the tympanomastoid fissure, after which it divides behind the pinna into two branches, one of which joins the posterior auricular branch of the facial, and the other ramifies in the posterior inferior part of the cartilaginous portion of the ear, and to the skin of the dorsal part of the pinna. It also supplies twigs to the bony part of the external auditory meatus, and to the lower part of the outer surface of the tympanic membrane.

The petrous ganglion

This ganglion lies around the glossopharyngeal nerve in the lower part of the jugular foramen. The motor and sensory roots are derived from the vagus and probably also from the facial and glossopharyngeal nerves. The sympathetic root is a fine filament derived from the superior cervical sympathetic ganglion.

The branches of distribution of the petrous ganglion are mainly through the tympanic branch, or nerve of Jacobson, to the tympanic plexus where communication is established with the facial nerve, and with two branches of the carotid nerve, the superior and inferior caroticotympanic nerves which enter the tympanic cavity through channels of the same name. From this plexus arises the small superficial petrosal nerve which goes to the otic ganglion. Other branches are distributed to the middle ear, and many filaments pass to the carotid plexus, while still others go to the pharyngeal plexus. Fibers also pass by way of the glossopharyngeal nerve to the tonsils.

The tympanic plexus serves as a common point of distribution of fibers from the carotid plexus, the cavernous plexus, and the superior cervical sympathetic ganglion, by way of the caroticotympanic nerves, and the jugular and tympanic nerves. The tympanic plexus communicates with the petrous, jugular, geniculate, otic and sphenopalatine ganglia, and the only cephalic ganglia of the sympathetic that it does not communicate with are the ciliary and submaxillary ganglia, which are supplied from the carotid plexus direct, or from plexuses derived from the carotid. The tympanic plexus is formed by nerves derived indirectly from the superior cervical sympathetic ganglion, the inferior caroticotympanic from the carotid plexus, the superior caroticotympanic from the cavernous plexus, and the tympanic nerve derived from the petrous and jugular ganglia which it has entered as the jugular nerve. The tympanic plexus communicates with the geniculate ganglion through a small branch which may be called the geniculotympanic ramus; it communicates with the sphenopalatine ganglion through the great superficial petrosal nerve by way of a branch that may be called the tympanopetrosal ramus; and it communicates with the otic ganglion by way of the small superficial petrosal nerve. It will be seen that the tympanic plexus with the carotid and derivitive plexuses and the cephalic ganglia enumerated above represent broken up cephalic portions of the gangliated sympathetic cord whose ganglia have fused more or less in the neck and have become scattered in the head. The tympanic plexus is the communicating plexus of the ganglia, and represents not only the rami communicantes, but the sympathetic trunks connecting the sympathetic ganglia. The ganglia of the glossopalatine, glossopharyngeal and pneumogastric nerves, that is, the geniculate, petrous and jugular ganglia, are different from the other cephalic sympathetic ganglia, in that the central and sympathetic portions have not become separated by the wandering off of the sympathetic portions. The ciliary, sphenopalatine, otic and submaxillary ganglia wandered off from the Gasserian ganglion at an early embryonic period, in a manner similar to the wandering of the sympathetic ganglia of the gangliated cord from the spinal root ganglia, and the four ganglia are true sympathetic ganglia. The sympathetic portions of the ganglia of the glossopalatine, glossopharyngeal and pneumogastric nerves remain fused with the spinal portions of the same ganglia, but the tympanic plexus forms a common ground of communication, and affords a ready means of understanding the relationship between all the cephalic sympathetic ganglia.

The geniculate ganglion

This ganglion lies embedded in the anterior border of the geniculum of the facial nerve dorsal to the hiatus Fallopii. Its motor root is of fibers from the facial nerve joining it at the great bend of the latter. The sensory root is derived from the dorsal root portion or the ganglion of the glossopalatine nerve, either in the ganglion or adjacent to it. The sympathetic root is the external superficial petrosal which passes through the hiatus Fallopii and connects the ganglion with the sympathetic plexus on the middle meningeal artery or through the great superficial petrosal nerve from the sphenopalatine ganglion. The branches of distribution of this ganglion pass through other ganglia, or other nerves. The great superficial petrosal nerve passes directly from the geniculate ganglion to the sphenopalatine ganglion. A communicating branch passes from the geniculate ganglion to the small superficial petrosal nerve which afterwards enters the otic ganglion.

The sphenopalatine or Meckel's ganglion

This ganglion and the three following may be described as in the anatomy of Morris, remembering to dissociate them from the trigeminal nerve. The important facts concerning these ganglia are to determine their motor, sensory and sympathetic roots of origin, and to establish their fibers of distribution. The three roots of origin, motor, sensory and sympathetic, of the sphenopalatine ganglion are from the facial, trigeminal, and great deep petrosal nerves respectively. The fibers are distributed to the mucous membranes lining the ethmoidal and sphenoidal sinuses, and that of the nasal, buccal and pharyngeal cavities. Fibers of taste belonging to the glossopalatine nerve, arising from the geniculate ganglion, pass through the sphenopalatine ganglion from the great superficial petrosal nerve, and are distributed to the soft palate. Some of the small palatal muscles may be supplied by motor branches passing through this ganglion without interruption.

The position of the sphenopalatine ganglion is determined by the size and shape of the sphenoid sinus. In many recent dissections I have found it medial, lateral or inferior to this sinus and in five subjects the Vidian nerve passed through the sphenoid sinus in a tube of bone covered with mucous membrane.

The otic ganglion

The motor root of the otic ganglion is derived from the motor nucleus of the facial and some fibers probably also from the masticator nerve. Its sensory root passes through it from the glossopharyngeal nerve, and its sympathetic root from the middle meningeal plexus and from the tympanic plexus through the continuation of the tympanic nerve in the small superficial petrosal nerve. The sympathetic fibers from the otic ganglion are distributed to the parotid gland, the glands and vessels of the tongue, and uninterrupted motor cranial fibers to the tensor tympani and tensor veli palatini muscles.

The submaxillary ganglion

The motor root of this ganglion is derived from the motor nucleus of the glossopalatine, the sensory root from the lingual (Gasserian ganglion) and the sympathetic root from the plexus on the facial artery, or from the sympathetic portion of the geniculate ganglion through the chorda tympani. The fibers arising from this ganglion are distributed to the submaxillary and sublingual glands and to the floor of the mouth.

The ciliary ganglion

The motor root of this ganglion is derived from the oculomotor nerve, fibers which terminate in it, the sensory from the trigeminal, and the sympathetic root from the cavernous plexus. The fibers from this ganglion are distributed to the ciliary body, the iris, the cornea, and probably to the lachrymal gland.

The parotid ganglion

A small plexiform mass containing ganglion cells, and located beneath the parotid gland on the auriculo-temporal nerve, connecting with the vagus, facial and trigeminal nerves, has been dissected repeatedly by students in the laboratory at Tulane University under my direction. At present investigations are under way to determine if this is the ganglion of the parotid gland. I realize that the term sympathetic needs restriction in its use, therefore, I propose that it be reserved for use in gross description, the sympathetic nervous system as a whole, in the same way that the terms central and peripheral nervous systems are used. In any presentation of the functional differences of neurones the terms somatic motor, somatic sensory, visceral motor and visceral sensory should be used insofar as present knowledge of the subject will permit.

From the standpoint of gross anatomy there can be no question as to the propriety of assembling the ganglia of the head and their connections as the ganglionated cephalic plexus, and from the standpoint of their sympathetic connections they are one, although it is desirable to determine exactly what fibers are motor, sensory or secretory, where they have their origin and where they are distributed.

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27. *On the development, attachment and action of the tectorial membrane.*

IRVING HARDESTY, Tulane University.

The beginning of the tectorial membrane appears in foetal pigs of 3 to 5 cm. long as an imperfectly fibrous, transparent film lying upon and produced by a thickening of the epithelium of the foetal cochlear duct along its axio-basal aspect. This band of thicker epithelium becomes the "greater epithelial ridge" of the later stages.

In foetuses of 6 to 9 cm., the greater ridge has become thicker and broader and appears only in the base of the cochlear duct, due to the invasion of its axial side by the mesencyhmal syncytium to form the vistibular lip of the spiral lamina. As this invasion proceeds, the axial cells cease to produce tectorial membrane and thus the axial edge of the membrane remains thin and is held adherent upon the vestibular lip. The now thicker film upon the greater ridge shows structure characteristic of the tectorial membrane. At the extreme lateral or outer margin of the greater ridge there is differentiating a line of cells, 2 or 3 wide, which cells are broader than their neighbors and when traced through the later stages become the rods of the organ of Corti, these cells and a few others about them increasing in height to from the "lesser epithelial ridge" (anlage of the organ of Corti) lateral to the greater ridge and tectorial membrane.

The greater ridge increases in both width and thickness, acquiring its maximum width in foetuses from 13 to 16 cm. Its cells are steadily contributing thickness to the basal side of the tectorial membrane, connected with it by 3 to 6 delicate fibers continuous from the distal end of each cell. The lateral or outer edge of the developing tectorial membrane here conforms closely to the rounded lateral margin of the greater ridge, cupping around this margin and fitting into the groove between it and the lesser ridge, the basal cells of this rounded margin coming to lie at almost right angles to the axis of the cochlea in order to be perpendicular to the edge of the membrane they are forming.

During the earlier stages of their differentiation, the cells of the lesser ridge (beginning organ of Corti) likewise produce a few filamentous threads and these threads are seen extending from their cells of origin and adhering to the vestibular surface of the outer edge of the developing tectorial membrane. These threads disintegrate in the later stages and thus contribute no part of the adult tectorial membrane. In structure, the tectorial membrane consists of a hyaline matrix, probably keratin, in gelatinous form, in which are imbedded the very numerous fine fibres or threads of uniform size, the varying directions of which are determined by the varying directions of the cells producing the membrane during the different stages of the increase and decrease of the greater ridge. The filaments produced by the cells of the early lesser ridge have ceased to grow in pigs of 16 cm., are never embedded in a matrix as are those of the tectorial membrane, are largely disintegrated at 19 cm., and have totally disappeared in foetuses near term.

In pigs from 13 to 16 cm. the cells forming the axial side of the greater ridge begin to decrease in height and number. Beginning at this axial margin, the cells gradually become divorced from the membrane they have produced, the process of divorce proceeding outwardly, the divorced cells receding and decreasing in number till they become the fewer, flattened cells lining the spiral sulcus of the adult. The last cells to become separated from their product are thus those immediately adjacent to the inner sustentacular cells of the organ of Corti. The recession and decrease in number is accompanied by an appreciable narrowing of the basal floor of the spiral sulcus. In foetuses of 15 cm., the width of the greater ridge may measure in the apical coils of the cochlea twice the width of the basal floor of the spiral sulcus in the adult. In the basal coil this decrease in width is only about one third of the width at 15 cm.

This developmental decrease of the distance between the organ of Corti and the vestibular lip of the spiral lamina results in the change in position of the organ of Corti with reference to the tympanic surface of the tectorial membrane and, of course, in a tearing free of the membrane from any attachment it may have with structures lateral to the vestibular lip of the spiral lamina. In the apical coils the membrane of the adult may come to extend not only over the entire organ of Corti but also over from 9 to 13 of the cells of Claudius. Thus the tectorial membrane is only attached along its axial edge upon the vestibular lip of the spiral lamina. Its outspanning portion is of necessity free.

From various measurements taken from 9 growth stages and from the adult, the most probable explanation of the final position, well under the tectorial membrane, acquired by the organ of Corti is that it is due to a growth in width of the vestibular portion of the spiral lamina resulting in an outer or lateral projection of the membrane over the organ, and in greater part to an actual shifting axialward of the organ of Corti coincident with the disintegration of the greater ridge.

In the adult pig the tectorial membrane is about 30 mm. long. In the apical turn it is about 5 times as wide and 5 times as thick as is its basal end; its area in section in the apical turn is approximately 21 times and its volume 95 times the area in section and the volume of its basal end.

Teased fresh specimens of the tectorial membrane show that it decreases evenly from its larger, apical towards its smaller basal end and it has sufficient elasticity, probably due to the arrangement of its fibers, to maintain its position over and approximate to the organ of Corti. Longitudinally it is exceedingly flexible, offering practically no resistance to stress applied transversely to its long axis.

An apparatus constructed to simulate the essential parts of the auditory apparatus is thought to indicate something of its functional action. The external meatus is represented by a large mouthed megaphone over the smaller end of which is stretched a piece of gold beater's skin for the tympanic membrane. The cochlear duct is a narrow, thick-walled box, 42 inches long, with a wooden spiral lamina and thin wooden basilar membrane and with drum-skin covered openings representing the fenestrae, at the basal ends of the scalae. The tectorial membrane is represented by a piece of very thick elk's hide pared to the shape and approximate proportions of the membrane and softened, and its thin edge affixed upon the vestibular lip of the spiral lamina. At 6 equal intervals fine platinum wires are passed through the membrane to make contact below with small copper plates representing the organ of Corti, the plates being continuous with wires and capable of being raised or lowered by means of adjustment screws beneath the box. Batteries are connected with the platinum and copper wires at each interval. The box, which has a water-tight, glass top, is completely filled with distilled water, the top fastened down without inclusion of air, and a representative of the ossicles is placed pressing between the tympanic membrane and the skin representing the fenestra ovalis. Telephones are interposed in the circuits made by contact of the platinum wires with the copper plates.

Ordinary organ reeds, having known vibration frequencies, were used chiefly in the experiments. These were sounded into the megaphone. It was found that any vibration from a step upon the laboratory floor up to the note G below 'middle C' (196 vibrations per second) would throw the membrane into vibration throughout its entire length. This note caused the membrane to vibrate more strongly at the fourth interval from its smaller end than at any other interval, indicating a certain amount of resonance in this region. A, the next note above, produced vibrations at all intervals of the membrane except the sixth, the apical end. Middle C, 261 vibrations per second, was damped out at the fourth interval. Notes above F, which is 349 vibrations per second, produced vibrations in no part of the membrane. Occasionally a note other than G produced more pronounced vibrations at a certain interval than at others but evidence of the existence of resonance were unsatisfactory.

From results with this comparatively coarse and crudely constructed apparatus, it is suggested that notes up to a certain pitch throw the entire natural tectorial membrane into vibrations of corrresponding frequencies and that sensations of pitch are determined by the frequency of impingement of the membrane upon the auditory hairs, intensity being determined by the amplitude and quality by the quality of the wave motion imparted. Further, that the highest notes within the range of the auditory apparatus throw, according to their frequency, only varying extents of the smaller, basal end of the tectorial membrane into vibration, being so damped out in passing toward the apex of the cochlea, overcoming friction, the inertia of the endolymph and that of the membrane itself, as not to produce vibrations in the heavier, apical portions. Finally, since, if the tectorial membrane varying in mass as it does were cut into a number of segments, each segment would have a different natural vibration frequency, it is possible that it exercises a certain amount of resonance. The diaphragm of the telephone possesses a small amount of resonance. The above results suggest a modification of the telephone theory of hearing.

REFORM IN EDUCATION

By Robert Bennett Bean

Some reflections as to the present status of education in America, reflections that have come as a result of extended studies in the eruption of the permanent teeth, have prompted me to suggest a scheme for saving time in education without loss of essential values otherwise. There is a waste of at least two years in the present plan of American education. This is the conclusion reached by a committee of prominent educators in a report on "Economy of Time of Education" just issued by the United States Bureau of Education, and I believe a greater waste than this is present.

The conclusion follows an investigation lasting nearly 10 years by a Committee of the National Education Association,[1] of which President James H. Baker, of the University of Colorado, is chairman. The committee have endeavored to form a plan that would do away with the two year loss. They propose that 6 years be assigned to the elementary school instead of 8 as at present; that the high school period be from 12 to 18, divided into two parts, of four and two years each; that college work extend from 18 to 20, or 16 to 20, according to the method of distributing the last two secondary years; and that graduate or professional work at a university cover the years from 20 to 24. This would enable boys and girls to get ample vocational training after the age of 12; it would enable those who go on to college to get through their college work at 20; and it would save the professional man from having to wait until 27 to start his professional career.

The report insists that the present elementary course is too long; that the ground now covered in 8 years can be covered just as efficiently in 6, allowing secondary work to begin at the age of 12. To save on elementary schooling they urge: "Choose the most important subjects and the most important topics; make a distinction between first-rate facts and principles and tenth-rate. Confine the period of elementary education to mastering the tools of education. Include the last two years of the present elementary school in the period of secondary education and begin the study of foreign language, elementary algebra, constructive geometry, elementary science, and history two years earlier than at present."

Emphasis is laid on the necessity of concentrating on a few valuable studies: "The great mistake of our education is to suppose that quantity and strain constitute education. Education is a question of doing a few essential things well and without over-strain. The college has committed a grievous mistake in demanding ever more in quantity rather than in quality produced under conditions of healthy normal development."

The report takes up the problem of saving time in education from the point of view of the college, the school, and society at large, as well as of the individual pupil; and it contains opinions on every phase of the question from representative school men and the general public.

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[1] *Economy of Time in Education.* Bulletin U. S. Bureau of Educ., 1913.

It has seemed to me that the professional man should start before the age of 24, because several years after graduation from a university should be devoted to experience in the profession before the actual work of life has begun, as is now being done in the medical profession by internes in hospitals. There is no more reason why inexperienced engineers, lawyers, or others should be foisted upon an innocent public than physicians. It is true that we should cut out the non-essentials in the primary schools, and lop off the excrescences, and there is much to be said in favor of repairing the foundation before the superstructure, but in a plastic system it may be well to begin in the middle and work both ways. A fitting capstone for a school system may become a suitable foundation for more advanced education. Compression may well be started with the university and the secondary schools, by allowing the first two years of the former to count also as the last two years of the latter and thus securing the Bachelor's and Doctor's degrees both in six years.

Education is the full rounding of the individual mentally, physically and morally, and should be approached from the biological standpoint as well as from any other. At the age of 16 years practically all the structures and functions have attained their competency, and at this time four vistas open before the youth on the threshold of life. The muscular, mental, sexual and alimentary activities are ready for ripening: exercise, study, the passions and the appetites are in full play. They may be grouped in two categories, motor and sensory. The muscular and mental activities are motor, the sexual and alimentary activities are sensory. The motor activities control the sensory, but if the sensory activities are ripened at the expense of the motor, the body may control the mind. It is essential that the motor activities become dominant, and that they may become so they must not only be exercised well, but as expressed by Henry James stresses and strains that reach the physiological limit of endurance will not only keep one occupied but will enable one to do more thereafter. The youth should be driven hard from 16 to 20 years of age because at that age the appetites and passions are strongest in youth, and this is the time when the mind and body are capable of responding to stresses and strains, therefore it is expedient at this time to give the mind the greatest amount of work it can endure, and to keep the body fit to nourish the brain, that by so doing the passions and appetites may be subordinated.

The crucial period of the 6 years course that I advocate for the completion of secondary and advanced education is the first two years, and this should come at about the age of 16 to 18 years. At the end of this time the student should have completed Mathematics through calculus; Latin, Greek and English; German, French and Spanish; Physics, Chemistry and Biology; and Civil Government. The courses should be complete, such as for instance in Chemistry through quantitative and qualitative analysis, organic and inorganic; and in Biology to include the dissection of a mammal, and the microscopic study of plant and animal tissues.

This should fit a person for anything whatsoever in life, and if advanced study is undertaken the next two years should be devoted to the fundamentals of the specialty selected, and the two years after that to the practical applications of the subject in the nature of original investigations.

The first two years work should entitle the participant to a certificate or degree of the fundamentals; the second two years to the Bachelor's degree; and the third two years to the Doctor's degree, which should be specific, as Doctor of Medicine, Doctor of Law, Doctor of English, Doctor of Engineering, Doctor of Agriculture, or what not. The first two years should be given in all the high schools, colleges, or other secondary schools, and well equipped teachers and laboratories should be provided for the courses of this period. All primary education should be raised to conform to this standard, and all advanced education would be raised following it. In this way the age of 18 would be the starting point for the young entering a business or other enterprise, the age of 20 would be the starting point for those who could not complete a professional education, and the age of 22 would be the starting point for the professions.

In consideration of the fact that at least four classes of students exist, a few exceptionally gifted, a few exceptionally poor, a large class of rapid workers and a large class of slow workers; or those who are unusually precocious, or unusually backward, and those who are only slightly precocious or slightly backward; in consideration of this, there should be at least four provisions made to meet the needs of all.

The selection of teachers is the most important task of the educator, and until the pay of teachers exceeds that of bricklayers, carpenters and plumbers, the best intellects will not be attracted to teaching except as a means of self-denial. The teachers in the primary schools should have the gifts of keen insight into human nature; the instincts of the born commander, and the power of imparting to others the essentials, whereas the teachers in advanced courses should have not only the powers of analysis and synthesis in productive thought, and the quality of exact observation with correct inference, but also the power of transmitting to others both inspiration and enthusiasm.

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THE STATURE AND THE ERUPTION OF THE PERMANENT TEETH OF AMERICAN, GERMAN-AMERICAN AND FILIPINO CHILDREN. DEDUCTIONS FROM THE MEASUREMENTS AND EXAMINATION OF 1445 PUBLIC SCHOOL CHILDREN IN ANN ARBOR, MICHIGAN, AND 776 IN MANILA, P. I.

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FIVE DIAGRAMS

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Data:	2221	school children
		630 Filipino boys
	776	146 Filipino girls
		322 German boys
	628	306 German girls
		407 American boys
	817	410 American girls
	2221	Total

INTRODUCTION

The records on which this study is based were made in 1906, 1907 and 1908 and have lain fallow for more than five years, because of excessive teaching duties and lack of library facilities. However, after an extensive survey of the literature I have come to the conclusion that no other study of its kind has ever been made, except that of Hrdlička on the North American Indians (31), and it was through the initiative of Dr. Hrdlička that this work was undertaken. Observations on the teeth of many people have been made from time to time but no extensive detailed observations have ever before been published, not even of Europeans, and no absolute standards have been established as to the time of eruption or extent of decay in males and females and from the standpoint of race. This study is an attempt in that direction, but leaves much to be desired, especially as the number of Filipinos examined at each age in the early years is but small.

MATERIALS

During the school term of 1906–07 I examined and measured every available child in the public schools of Ann Arbor. This was made possible through the coöperation of Dr. McMurrich, and the superintendent of schools and the teachers who showed commendable zeal in furthering the work. The teeth of the children were examined by Dr. Bunting who also assisted me in making the records. Two groups of children were segregated, one of American parentage solely, the other of German, or American and German parentage. The titles American and German will be used for the two groups. When taken together the German and American children will be called European. Children were grouped as German if two grandparents or if either parent came from Germany, and whenever the name was German and the parentage was not given the child was included in the German group, although there were only a few records of this kind. There is a large colony of Germans both in the town of Ann Arbor and in the adjacent country and the majority of the Germans included in the records are of pure German extraction. A large number of children of the teaching staff at the University of Michigan are included in the American group and a large number of rural children are included in the German group. The whole lot of children may be called sub-urban.

The Manila school children were examined by myself in 1907–08 at the Normal and Trade schools, where pupils from all parts of the Philippine Archipelago come to be educated as teachers and mechanics, carpenters, etc. The young children attend classes taught by the older ones at the Normal School and are necessarily from Manila and vicinity. The majority of the children are mestizos, mixed Spanish, Chinese and Filipino, and represent the littoral population of the archipelago fairly well. A few individuals are probably of pure Spanish extraction. No attempt was made to segregate the mestizos or those of Chinese or Spanish extraction from the presumably pure Filipinos because any such attempt is necessarily imperfect and will be so until we understand better than we do at present the workings of Mendelian heredity in man.

METHODS

The age of the children was obtained from each individual and verified as far as possible through the teachers. In Manila the school registers were also examined and the age verified in this way. Discrepancies occur in spite of all efforts to avoid them, but I believe nearly all the ages are exact, and the few that may not be are approximately correct. The year and the month of birth were obtained in all except a few instances and the child reckoned to be a certain age if it is anywhere within six months of that age. For instance, if a child was born in January 1902 and the records were made in July 1908, the child was recorded as six years old, but if the records were made in July 1907 the child was recorded as five years old, and if the records were made in August, 1908, the child was recorded as seven years old. This method is practically the same as obtaining from the child the nearest birthday, although in giving that the child is apt to miscalculate.

The stature was obtained by using a stationary vertical graduated scale with sliding arm to come down on the child's head. This was pressed firmly and several readings were made for each record, the child standing erect with its back against the scale. The children were measured without shoes when feasible, otherwise allowance was made for the height of the shoe heel. The average or 'mean' stature is used although the 'median' and the 'mode' will be presented.

Many other measurements were made, including sitting stature, weight, head and face dimensions, with observations of the hair and eyes, but these are reserved for future publication. The teeth were examined for eruption, decay, absence, or irregularity. For detailed observations see the table of records, which shows the condition of eruption and decay of each tooth in each individual, and will be published either separately or on file in The Wistar Institute of Anatomy in Philadelphia.

The standard deviation, coefficient of correlation, probable error, etc., are not given, because the characteristics of the individual rather than the mass are desired. However, the average, the mean, the mode, and the extremes have been computed, and these with other factors are utilized in an attempt to determine individual characteristics.

At the end the morphologic type, the sex, and the race are used to assist in explaining individual differences, such as why one child has a certain tooth erupted 5 years earlier than another child has the same kind of tooth erupted, which occurs with great frequency.

THE STATURE

1. *Stature of the groups compared*

It is to be noted that all the boys and girls of each group have about the same stature at the age of seven years, and the stature varies more both before and after this age. At five years the Igorot boys are 97 cm. tall, the Filipino boys 105.8 cm. tall, the German boys are 107.5 cm. tall, the German girls 110.8 cm. tall, and the American girls and boys each 112.5 cm. tall. The difference between the smallest and tallest group at five years is 15.5 cm., whereas the difference at seven years is only 4 cm. There are so few individuals at the age of five years in each group, the greatest number in any group is five individuals, that the differences given are of slight importance.

After the age of seven years the differences become significant. The Igorots are still much below the average of any other group, and the Filipino boys are also low in stature, but between 12 and 15 years very nearly equal to the German boys. There is a constant decrease in the increment of growth in the Filipino girls, which decrease from the age of seven years onward is greater than that of any other group.

The growth of the Filipino girls almost ceases between 14 and 15 years, and there is apparently no growth after the age of 18 years. The stature of the Filipino boys is less than that of the Filipino girls until the age of 12 years is reached at which time the boys pass the girls in a rapid growth that decreases suddenly at the age of 17, although there is a slight increment of growth in the Filipino boys even after the age of 20 is passed.

The stature of the German girls is less than that of the German boys before the age of 11, greater between the ages of 12 and 14, after which it is again less, but very slightly so. There is a sudden check in the growth of the German girls at 14 but after 15 the growth again accelerates. The growth of the German boys is fairly uniform throughout and there is no evidence of cessation at the age of 16. The growth of the German boys is, however, slightly more rapid after the age of 12 than before. There is also a slight acceleration of growth in the German boys up to the age of 8 and a slight retardation between the ages of 8 and 12.

The stature of the American boys and girls crosses and recrosses up to the age of 10 years, that of the girls in general is less before this age. Between the ages of 10 and 11 the stature of the girls becomes greater than that of the boys until the age of 14 is reached when the growth of the girls ceases, to continue slowly after the age of 15, at which time the stature of the girls becomes less than that of the boys, and it remains so thereafter. The growth of the American girls from 15 to 17 years of age is retarded at a slightly slower rate than that of the Filipino boys, and there is a fairly uniform parallel growth of the two except for the sudden cessation in growth of the American girls from 14 to 15 years, the American girls at all ages being taller than the Filipino boys. The growth of the American and German boys is fairly parallel, the American boys slightly taller at each age except 8 when the German boys are taller. The American boys' growth is retarded from 5 to 7, accelerated from 7 to 10, again retarded from 10 to 13.

The stature of the American and German girls is fairly parallel until the age of 15, the German less than the American, but after the age of 15 the stature of the German girls exceeds that of the American girls.

In general the stature of the Filipino is less than that of the German and the stature of the German less than that of the American. The growth of the Filipino girls and boys and of the American girls has its final retardation earlier than that of the German girls and boys and American boys, the last three giving no evidence of this when the records cease at 18 years of age.

The stature of the Filipinos beyond the age of 20 is greater by 5.2 cm. than that of the adult Filipinos of Taytay (3), a village near Manila. The boys belong to the well-to-do class. The Taytayans are poor which may account for this difference. The Taytayans are also less mixed with the Spanish and Chinese than the school boys which is another factor in accounting for the difference in stature.

The stature of the Filipino boys is 11 cm. greater than that of the girls beyond the age of 20, and this is in excess of the usual sexual difference, which is often not more than 5 cm. This may be due to a greater inheritance of the father's stature by the boys and of the mothers' stature by the girls because the fathers of many of the children are Spanish and Chinese and the mothers are Filipinos, and the stature of the Spanish and Chinese is greater than that of the Filipinos. This may be a confirmation of Pearson's findings that males inherit stature from the father and females from the mother.

There are so few Filipinos below the age of 16 for each sex that the average has only an approximate value. There is also greater variability in stature at the ages of 12, 13 and 14 among the Filipinos, than either before or after. For instance at the age of 10, the extremes are only 15 cm. apart, and at the age of 15 only 25 cm. apart, whereas at 12, 13 and 14 years, they are 30, 35 and 35 cm. apart respectively. It is noted that the German and American children exhibit a variability that is greater with advancing years. The reverse is true of the Filipinos.

2. Review of literature and discussion

When the stature of the Ann Arbor boys of American parentage is compared with the stature of the Boston boys (13,691, Bowditch (11)) of American parentage it is found that the Ann Arbor boys are about 5 cm. taller at the ages of 5 and 6, and this difference decreases until the age of 15 is reached after which the boys of both places have about the same stature. This is true also of the Nebraska boys (5,476, Hastings (26)) when compared with the Ann Arbor boys, and the difference with them at the early ages is even more marked in favor of the Ann Arbor boys. It is evident that the boys of Ann Arbor attain their early stature quicker than the boys of Boston. This is probably due to the fact that the children of Ann Arbor have a more favorable environment than the children of Boston. Bowditch found that the boys of the private schools in Boston were taller than the boys of the public schools, and taller than the boys of the laboring classes in England. It is generally recognized that the children of the well-to-do grow more rapidly than the children of the poor, that is, early in life. There may be some influence due to the selected parentage and not alone due to environment. A great number of the boys examined at Ann Arbor were children of members of the Faculty of the University of Michigan, or children of students, and this might have some influence.

The German boys of Ann Arbor (324, Bean) are also taller than the German boys of Boston (752, Bowditch), although this difference is only about 2 or 3 cm. until the age of 15 is reached when both groups become equal in stature. This difference may be due to environment alone because the Germans of Boston and Ann Arbor probably come from a similar stock.

The same difference that exists between the American boys of Ann Arbor and of Boston exists to a limited extent between the girls of the two places. The girls of Ann Arbor (409, Bean) are about 5 cm. taller at the age of 5 and 6 years than the Boston girls (10,874, Bowditch) of the same age and this difference decreases until the age of 15 is reached, at which time the stature is only about 2 cm. apart. The Ann Arbor girls pass the Ann Arbor boys in stature a half year earlier than this takes place in Boston (Ann Arbor, 10, Boston 10½) and the boys do not again reach the stature of the girls in Ann Arbor until a half year later than in Boston (Ann Arbor 15 years, Boston 14½ years).

Peckhan (44) reports the results of measuring 5,136 girls, and 5,117 boys of Milwaukee, in which the boys, both German boys and American, were taller than the Boston boys from 13 years onward (Bowditch 13,691 boys, 10,874 girls), with a rapid increase of stature from 16 to 19 years. The girls at all ages both German and American were taller than the Boston girls. The Milwaukee children differ from the Ann Arbor children in that the former have a late rapid growth whereas the latter have an early rapid growth. Is the late rapid growth of the Milwaukee children due to the Norse (long head) stock and is the early rapid growth of the Ann Arbor children due to the large south German (broad head) element? Or is it a matter of environment?

Schwerz (47) reports the results of measuring 960 boys and 818 girls of Schaffhausen, Switzerland, in which the Swiss boys are 4 cm. less in stature at all ages than the Ann Arbor American boys, and the increase in rate of growth is at about the same periods, 9, 14 and 17 years. The Ann Arbor German boys have 1 or 2 cm. greater stature than the Swiss boys until the age of 14 years after which the German boys attain a stature which is 4 cm. greater at 15 years and 7 cm. greater at 16 years, this, too, in spite of the fact that the Swiss boys are six months older at each period than the Ann Arbor German boys. The differences that exist between the Swiss boys and the Ann Arbor German boys also exist to about the same extent between Swiss girls and Ann Arbor girls. The periods of rapid growth are about the same in the two groups.

The cephalic index, face index, etc. of the two groups are about the same thus signifying that the two groups, Swiss and Ann Arbor Germans, are of the same stock, the Alpine or middle European, rather than of the Nordic or Mediterranean stocks. Schwerz compares the Berlin German children with the Turin Italian children in both the poorer classes and the well-to-do classes, with the result that the Berlin children are taller at each age in both classes and both sexes. The well-to-do boys of Berlin have about the same stature at all ages as the American boys at Ann Arbor and the boys of the poor in Berlin are only slightly less tall at each age (1 to 2 cm.) than the Ann Arbor German boys. The well-to-do girls of Berlin are slightly taller at each age than the American girls of Ann Arbor, and the poor girls of Berlin are only slightly less tall (1 to 2 cm.) than the Ann Arbor German girls. The Turin boys and girls are in all groups, and at all ages from 5 to 10 cm. less in stature than the Berlin children. Thus the three stocks of Europe, Nordic, Alpine and Mediterranean, are represented by the Berlin, Schaffhausen and Turin children respectively (?) and it would appear that the Milwaukee children are Nordic, the Ann Arbor American children are Nordic and Alpine, and the Ann Arbor German children are Alpine. The effect of nutrition or environment cannot be stated for the several groups but no doubt its influence accounts for some variation.

When the Filipino boys measured by Bobbitt (10) are compared with those I measured, the difference in stature is in favor of the latter to the extent of about 2 cm., after the age of 11 years; at 10 and 11 the two groups are equal, and before that Bobbitt's Filipino children are on the average 1 cm. taller down to and including the age of 6.

I measured only 11 Filipino girls below the age of 12 years, therefore they need not be considered. From 12 years onward, however, the girls measured exceed those measured by Bobbitt from 1 cm. at 12 and 13 years, to 5 cm. at 20 years and over. Not only this but Bobbitt gives the age from one birthday to the next as of the preceding birthday, whereas I give the age as of the six months before and after the birthday. For instance, he gives all children from 10 to 11 years of age as 10 years of age, whereas I give all children 9 years 6 months to 10 years 5 months as 10 years of age. His Filipino children are not only smaller but in each group are six months older than the same group given by me.

The children measured by Bobbitt were of three sorts. The oldest were about 75 per cent from the provinces, the youngest were largely from Manila and the intermediates were about equally divided between the two places. The majority of the children I measured were from the provinces, except those below the age of 10 years, who were all from Manila. Bobbitt did not include children who had evidence of mestizo blood (Spanish and Chinese), whereas I included all the children as they became available, regardless of race or color. A few were crosses of the American white and Filipino: the differences in stature may be explained by the greater amount of foreign blood in the children I measured, although when the children from the provinces are in the majority the stature is taller than when the children from the city of Manila are in the majority. It appears that European stock and rural environment may both increase the stature of the Filipino.

3. Periods of acceleration and retardation in growth

Growth occurs in waves. A period of acceleration is followed by a period of retardation. The periods occur at different times in the different sexes and races.

The first period of acceleration of which we have any record occurs between the ages of 6 and 10 years, after which there is a retardation followed by another acceleration about the age of 13 to 15. These periods may be of interest in relation to the eruption and decay of the teeth.

Disregarding the first and second periods of rapid growth, of which we have no record here, it may be seen that the third period of growth begins at about the age of 7 years and continues until about the age of 10, being most rapid from 7 to 8, and at the age of 10 years the third period of growth begins.

The third and fourth periods of rapid growth are earlier for the girls than for the boys and the fourth period of rapid growth is shorter for the girls than for the boys. The result is that the girls become larger than the boys between the ages of 7 and 15, and remain so until the fourth acceleration sets in for the boys, when they outstrip the girls in stature and remain taller thereafter.

The stature of the Filipinos is less than that of the Germans and Americans and this becomes more evident after the age of 14 years.

The stature of the Igorot boys is less than that of the Filipino boys and girls except at the ages of 7 to 8 when it is greater than that of the Filipino boys, and at the age of 20 when it is greater than that of the Filipino girls.

The Igorot boys attain their growth later than either the Filipino girls or the Filipino boys, but earlier than the German or American boys and girls.

The four groups may be arranged in order of precocity of acceleration periods as follows: 1, Filipino; 2, Igorot; 3, German; 4, American. The acceleration periods of the German begin earlier than those of the American but the ultimate stature is reached later in the German. This follows a law, general in nature, that the precocity or rapidity of development is inverse to the ultimate size.

The precocity of the group is inverse to the ultimate stature; the Americans, the tallest, the Filipinos, the smallest, with the Igorots and Germans intermediate: the Germans taller than the Igorots.

The Filipinos may have an early rapid development which is from the European standpoint premature, and a late maturity that is incomplete, at least it looks as if growth is continued up to a later age in the Filipinos than in the Europeans, but the extent of development is less.

The Ann Arbor American children, the Milwaukee and the Berlin children are similar in stature and in periods of growth. The Ann Arbor German children, the Boston German children and the Swiss children are likewise similar in stature and in periods of growth. The Swiss children, however, show considerable retardation in growth from the age of 15 onwards, whereas the American German children show no retardation until the age of 17 is reached. All the six groups are different from the Turin children of South Europe. In the latter there is an early rapid growth followed by retardation, and a later rapid growth followed by retardation that is earlier than in the other groups. In this they resemble the Filipinos.

The urban children of Boston are less rapid in their early development than the sub-urban children of Ann Arbor and the urban children of Milwaukee are more rapid in their late development that the sub-urban children of Ann Arbor. The early development of the Ann Arbor and Milwaukee children is about the same and the later development of the Ann Arbor and Boston children is about the same.

Factors in race and climate or heredity and environment both probably cause these differences. Neither can be excluded.

THE TEETH

The consideration of the teeth will be taken up under the following headings: 1. The eruption of the permanent teeth; 2. The alternation of growth in stature and eruption of the permanent teeth; 3. The eruption of the individual permanent teeth; 4. Review of the literature and discussion.

The youngest children whose teeth I examined were five years old, and at that age all the temporary teeth have erupted, therefore the time of the eruption of the temporary teeth cannot be given. The decay of the temporary teeth occurs partly after the age of five years, and this will be considered, in addition to the eruption and decay of the permanent teeth.

1. The eruption of the permanent teeth

This is determined by taking the average number of teeth erupted or erupting at each age, as well as the 'median,' the 'mode' and the 'extremes,' after which the periods of acceleration and retardation in the eruption of the permanent teeth will be given.

The eruption of the permanent teeth begins about the age of 5 years, slightly earlier among the girls and slightly later among the boys of the German and American groups, but considerably earlier than this among the Filipinos of both sexes. The Germans and Americans of both sexes have almost exactly the same number of permanent teeth at the ages of 6, 7 and 8 years, after which the girls have a greater number of teeth than the boys until the age of 15 is reached, when the number of teeth in the two sexes is again about the same.

The girls of each group are more precocious in the eruption of the permanent teeth than the boys, they have a greater number of permanent teeth at each age, and the difference is greatest between the ages of 8 and 15 years, for at the age of 11 years the American girls have an average of 21.3 permanent teeth present, and the American boys have an average of only 17.3. The difference between the German boys and girls at this age is not so great, and they have only 16.7 and 19.5 teeth present for the boys and girls respectively. The difference between the Filipino boys and girls is still less, and they have a greater number of teeth present than either the German or Americans at the age of 11 years, 24.3 and 27.0 for the boys and girls respectively.

The Filipinos are much more precocious than either the Germans or Americans in the eruption of the permanent teeth, and there is little difference between the boys and girls in the number of teeth present at each age. The Americans are a little more precocious than the Germans in the eruption of the permanent teeth, and the difference between the boys and girls is greater among the Americans than among the Germans and Filipinos.

About the age of 15 years the children of both sexes in all the groups have nearly the same number of teeth, and after this age the German and American children maintain the same number of teeth up to the time at which the records cease (18 years), but the Filipino children continue to gain in the number of their teeth to the age of 20 and beyond, although the majority of the Filipinos have acquired the complete set of 32 teeth at the age of 20 years. This is due to the early eruption of the third molars among the Filipinos (begins at 13) and their later eruption among the Germans and Americans (begins at or after 16).

Sixty odd negro boys and girls, mostly mulattoes, were examined at Ann Arbor, and it is found that the negro boys and the American boys are almost parallel in the time of the eruption of their teeth, and the negro girls are only slightly more precocious than the American girls.

2. The alternation of growth in stature and the eruption of the permanent teeth

The eruption of the permanent teeth does not occur with the same rapidity at each age, but there are waves of eruption of the teeth like the waves of growth, although the two are not synchronous. The periods of acceleration in the eruption of the permanent teeth occur about the ages of 7 and 11 years, and the periods of retardation follow those of acceleration. It will be seen that the periods of acceleration in the eruption of the permanent teeth initiate or precede the periods of rapid increase in stature. The eruption of the teeth through the gums is but evidence of their previous rapid development, and there is doubtless a period of rest throughout the body between the periods of rapid development of the teeth and the periods of rapid growth in stature.

Others have repeatedly demonstrated that the six months following birth is a period of rapid increase in length of the infant, which is followed by the eruption of the temporary teeth, all of which are through the gums by the age of three years. After this there is a period of rest which is followed by a second period of growth in stature about the age of five years, succeeding which the permanent teeth begin to develop, and this development is most rapid about the age of 7 years. This is followed by the third period of rapid growth in stature about the age of 8 years after which comes a period of rest and then the second acceleration in the eruption of the permanent teeth occurs between 10 and 11 years. The final rapid growth in stature comes after this at about 12 years of age, and immediately precedes puberty. Following puberty the increase in stature and the eruption of the teeth are delayed, especially in the girls. However, the third period of the acceleration in the eruption of the teeth (second period of acceleration in the eruption of the permanent teeth), the girls are about one year earlier than the boys, and the period of growth following this is about two years earlier in the girls than in the boys; (see The law of alternation in development, p. 137).

Résumé. After this brief consideration of the average or 'mean,' time of eruption of the permanent teeth, the 'median,' the 'mode' and the 'extremes,' as well as the periods of acceleration and retardation in the eruption, it is to be noted that the second teeth begin to erupt about 5 years of age, slightly earlier among the girls than among the boys and earlier among the Filipinos than among the Germans and the Americans, and latest of all among the Germans.

The girls are more precocious in the periods of acceleration of the eruption of the teeth than the boys, as well as in the average number of teeth, the 'median' and 'extremes' at any age. The

Filipinos are likewise more precocious than the Americans, who are slightly more precocious than the Germans.

There is an alternation in the periods of acceleration and retardation in the eruption of the permanent teeth, and there is also an alternation in the periods of acceleration of the growth in stature and the periods of acceleration in the eruption of the permanent teeth.

3. The time of eruption of each individual tooth

This is to be determined for each sex and race by means of the beginning of eruption, the end of eruption, and the average per cent of the teeth erupted at specified ages during which time the teeth are erupting in all the groups. The beginning of eruption may be utilized: that is the time at which the tooth first erupts in any individual in a race-sex group; the end of eruption, that is the time at which the tooth last erupts in any race-sex group; the 'median,' the time half way between the beginning of eruption and the end of eruption, may be taken as the time of eruption; or the time when 50 per cent of the teeth of any type have erupted in a sex-race group may be taken as the time of eruption. For purposes of comparing the groups with each other the average number of teeth erupted at the ages in which all the comparable groups have the teeth erupting at the same time may be utilized. This may be called the average per cent. As, for instance, the right upper second molar is erupting in all the groups during the ages of 12, 13 and 14 years, and the average per cent erupted at these ages is as follows:

	per cent		per cent		per cent
Filipino boys	85	American boys	53	German boys	51
Filipino girls	94	American girls	68	German girls	58

From this we may gather that the Filipinos are more precocious than the other two groups, the Americans are more precocious than the Germans, and the girls are more precocious than the boys in the eruption of the right upper second molar teeth.

The median incisors. The median incisors begin to erupt in some individuals before the age of five years, and the teeth are nearly if not all through the gums at the age of 10 years. There is practically no difference in the time of eruption on the two sides, but the lower median incisors erupt about a year earlier than the upper, a little less than a year on the left side and a little more than a year on the right side.

The median incisors erupt in the following order: (1) lower right; (2) lower left; (3) upper left; (4) upper right. The left upper median incisors erupt at approximately the same time in the Germans and Americans, the left lower erupt earlier in the Americans than in the Germans, and the right upper erupt earlier in the Americans than in the Germans, although the German girls may be slightly more precocious than the American girls. The median incisors erupt earlier in the Filipinos than in either the Germans or Americans. The median incisors erupt earlier in the German and American girls than in the German and American boys.

The lateral incisors. The lateral incisors begin to erupt in some individuals as early as the age of 6 years, and the teeth are nearly if not all through the gums at the age of 13 years. There is practically no difference in the time of eruption on the two sides, but the lower lateral incisors erupt about a year earlier than the upper, a little less than a year on the left side and a little more than a year on the right side.

The lateral incisors erupt in the following order: (1) lower right; (2) lower left; (3) upper left; (4) upper right. The lateral incisors erupt earlier in the girls than in the boys. The lateral incisors erupt earlier in the Filipinos than in the Germans and Americans, although there is very little difference in time for the eruption of the lower teeth of this type.

There is so little difference in time of eruption between the Germans and Americans that they may be considered as having the lateral incisors erupted at the same time, but the slight difference indicates that the Germans are more backward than the Americans.

The canines. The canines begin to erupt in some individuals as early as the age of 9 years, and the teeth are nearly all if not all through the gums at the age of 15 years. There is practically no difference in the time of eruption of the canine teeth on the two sides of the mouth but the lower canines erupt earlier than the upper. The difference in time between the eruption of the lower and upper canines is about one year in the American boys, less than a year in the German boys, and more than a year in the German and American girls. There is no order of eruption of the canines except that the lower erupt earlier than the upper.

The canines erupt earlier in the girls than in the boys, except that the upper canines erupt earlier in the Filipino boys than in the Filipino girls. The sexual differences amount to at least two years for the Filipinos, between one and two years for the Germans, and about one year for the Americans.

The upper canines erupt at about the same time in the Filipino, German and American girls, but the lower canines erupt at least three years earlier in the Filipino girls than in the German and American girls. There is almost no difference between the German and American girls in this. The canines erupt anywhere up to four years earlier in the Filipino boys than in the American or German boys, and the American boys are slightly more precocious than the German boys. The Filipinos of both sexes are precocious in the eruption of the canine teeth, the Germans are backward and the Americans are intermediate.

The median premolars. The median premolars begin to erupt in some individuals as early as the age of 8 years and the teeth are nearly if not all through the gums at the age of 15 years.

There is practically no difference in the time of eruption on the two sides of the mouth, but the upper median premolars erupt slightly earlier than the lower, although this difference is considerably less than one year.

The median premolars erupt in the following order: (1) left upper; (2) right upper; (3) right lower; (4) left lower. The median premolars erupt first in the Filipinos, second in the Americans and third in the Germans, although the differences are not great between the last two. The median premolars erupt earlier in the girls than in the boys, except that apparently the upper premolars erupt slightly earlier in the Filipino boys than in the Filipino girls, but this is questionable.

The lateral premolars. The lateral premolars begin to erupt in some individuals at the age of 8 years, and they are all through the gums in all individuals at the age of 16 years. There is very little difference in time of eruption on the two sides of the mouth, especially of the lower lateral premolars, although the left upper erupts earlier than the right upper. The order of eruption is as follows: (1) left upper; (2) right upper; (3) right lower, and (4) left lower. The upper lateral premolars erupt less than a year earlier than the lower.

The lateral premolars erupt first in the Filipinos, and second in the Germans and Americans, at almost the same time for each of the latter. The lateral premolars erupt earlier in the girls than in the boys.

The first molars. The first molars begin to erupt in some individuals before the age of five years, and nearly all, if not all, the first molars are erupted in all individuals at the age of 12 years.

There is practically no difference in the time of eruption of the first molars on the two sides of the mouth, but the lower first molars erupt slightly earlier than the upper, therefore the order of eruption is (1) and (2), lower first molars, (3) and (4), upper first molars. The lower first molars erupt earlier than the upper, the interval being considerably less than a year. The first molars erupt later in the Filipinos than in the Germans or Americans who are almost exactly alike in the time of eruption of these teeth.

The first molars erupt about one year earlier in the girls of each group than in the boys.

The second molars. The second molars begin to erupt at about the age of 10 years—slightly earlier in the Filipinos—and their eruption is completed in all, or nearly all, the individuals at the age of 16.

There is practically no difference in the time of eruption of the second molars on the two sides of the mouth, but the lower second molars erupt about a year earlier than the upper, therefore the order of eruption is (1) and (2) lower second molars, and (3) and (4) upper second molars. The second molars erupt earlier in the Filipinos than in the Germans and Americans, and earlier in the Americans than in the Germans.

The second molars erupt more than a year earlier in the girls than in the boys, except in the Filipinos, where the boys are slightly more precocious than the girls, although the lower second molars erupt earlier in the Filipino girls than in the Filipino boys.

The third molars. The third molars begin to appear in the Filipinos at the age of 13, and from 61 per cent to 83 per cent of the third molars have erupted in the Filipinos at the age of 20 and over.

The third molars have appeared in none of the German and American boys up to the age of 18 years, but they begin to appear in the American girls at the age of 16 years, and the left lower third molar has begun to erupt in the German girls also at the age of 16 years. The girls therefore appear to be more precocious in the eruption of the third molars than the boys, and the American girls more precocious than the German girls. The latter is not true among the Filipinos at the beginning of eruption, which occurs first among the Filipino boys, but as age advances up to 20 the Filipino girls become more advanced than the Filipino boys, and at the age of 20 and thereafter the girls have a greater average number of third molar teeth erupted than the boys.

There is practically no difference in the time of eruption of the third molar teeth on the two sides of the mouth, but the lower third molar erupt slightly earlier than the upper.

Résumé. On pages 128 to 132 we have considered the eruption of the teeth from the standpoint of the beginning of eruption, the end of eruption, and the average per cent. The results are as follows: The order of eruption in groups is (1) Filipino girls, (2) Filipino boys, (3) American girls, (4) German girls, (5) American boys, (6) German boys.

The order of the eruption of the individual teeth of the German and American group is (1) lower median incisors, (2) lower first molars, (3) upper first molars, (4) upper median incisors, (5) lower lateral incisors, (6) upper lateral incisors, (7, 8) upper median premolars and lower canines, (9) lower median premolars, (10, 11) upper lateral premolars and upper canines, (12) lower lateral premolars, (13) lower second molars, (14) upper second molars, (15) lower third molars, (16) upper third molars.

The order of eruption of the individual teeth in the Filipinos is the same as the above except that the lower first molars and the lower median incisors erupt at the same time, the upper median incisors and the upper first molars change places, the lower canines erupt before any of the premolars, and the upper canines erupt at the same time as the upper median premolars.

If these results are compared with those obtained from the time at which 50 per cent of the teeth are erupted little difference will be found. The order of eruption in the sex-race groups is the same, and the order of eruption of the types of teeth is the same, but the order of eruption of a few of the individual teeth is slightly different. This is manifest chiefly in the relative time of eruption of the first molars and median incisors, and of the canines and premolars. The meaning of this is that the first molars and median incisors are intimately related in time of development, if they are not synchronous, and the same is true of the canines and premolars. In either case the canines are more precocious in the Filipinos than in the Germans and Americans.

4. Review of the literature and discussion

We may arrange the teeth in the order found in their eruption among the German and American children of Ann Arbor taking the time at which 50 per cent have erupted and with this compare records for the French by Magitot-Broca (12, 13, 36, 37, 38, 39), Mayet (40), and Cherot (14), for the German by Welcker (51), and for the English by Livy (35).

It may be said that the time of the eruption of the teeth as given by Cherot for the French is almost the same as that of the Ann Arbor German and American children, or only a little earlier, whereas those of Magitot-Broca, and Mayet for the French are earlier, and those of Welcker for the Germans are later than those for the Ann Arbor children. The records of Welcker are only slightly later than those for the Ann Arbor German boys and those of Magitot-Broca are about the same as for the Ann Arbor American boys. The Americans and the French appear to be more precocious than the Germans. The English are precocious in the eruption of the lateral premolars, and backward in the eruption of the lateral incisors, but otherwise they conform fairly well in the eruption of the teeth to the Germans.

It is generally recognized that girls are more precocious than boys in the eruption of the teeth, and that the lower teeth erupt earlier than the upper, except the premolars, but Livy found among 4,000 children of the workers of Bolton, England, that the upper canines invariably precede the lower in the girls, whereas the lower canines invariably precede the upper in the boys. The upper canines erupt a year later than the lower among the German, American and Filipino girls that I examined, and less than a year later among the boys of the three groups.

Spokes (48) found among British children that the eruption of the canines occurs between the time of eruption of the median and lateral premolars, which is a verification of what I found among the German and American children of Ann Arbor, but among the Filipinos the canines erupt before the premolars. I found that the lower canines erupt between the time of eruption of the upper and lower median premolars, and the upper canines erupt between the time of eruption of the upper and lower lateral premolars. This may explain the contention of Owen (51) of England on the one side, who contends that the canines erupt before the premolars (canines, 7 to 9 years, premolars, 8 to 10 years), and Welcker, Sommering (51), Hyrtl (51), Henle (54), and Blumenbach (51) on the other, who contend that the median premolars erupt before the canines. It may be, however, that the canines erupt earlier among the British than among the Germans, just as the canines erupt earlier among the Filipinos than among the children of Ann Arbor, or at least this may be true for some parts of the British Empire. Livy did not find it so for the children of the laboring classes of Bolton, England.

The work of Cherot is of value because it is of recent date, and because he procured data from 20 to 30 children of each sex at each age. The time of the beginning of eruption and of the end of eruption as he found them in the French may be compared with my records of the Ann Arbor children.

It is to be seen that the French children are earlier than the children of Ann Arbor both in the beginning of eruption and in the end of the eruption of the teeth, except in the beginning of eruption of the lower median incisors and upper canines, wherefore it is evident that the French at any age are more mature in the eruption of the teeth than the children of Ann Arbor.

Cherot believes there are four periods of acceleration in the eruption of the permanent teeth, from six to eight and a half years when some teeth are erupting all the time; from 10 to 11 years; at 12 years; and about 20.5 years during the eruption of the third molars. The periods of 10 to 11 and at 12 should be combined because they run together, thus leaving three periods, which have been associated by others with the eruption of the three series of molar teeth. The periods of dentition given by Cherot would then correspond to the periods of acceleration given on page 127.

Hrdlička (30, 31) has published the only detailed data of the examination of children's teeth that I have been able to find in the literature. He examined the teeth of the Apache and Pima Indians of North America, and from his records he concludes that the teeth of the Indians appear at about the same ages as the teeth of the whites, with the exception of the canines and second molars which apparently erupt earlier in the Indians than in the whites. I have calculated the beginning of eruption and the end of eruption of the teeth in the Indians, which is based on the stature rather than the age, because the age of the Indians was not obtained by Hrdlička. The age is calculated from the stature by Hrdlička, and he remarks that it is doubtless imperfect.

The order of eruption is similar to that of the Europeans or white peoples, and different from that of the Filipinos, because in the latter the canines erupt before the premolars, whereas in the others the canines erupt at the time of the eruption of the premolars, or as noted above: the lower canines erupt between the eruption of the upper and lower median premolars and the upper canines erupt between the eruption of the upper and lower lateral premolars.

The eruption of the teeth begins later in the Indians than in the whites, and ends earlier. The teeth of the Indians erupt more promptly than those of the whites and the canines, second and third molars erupt earlier in the Indians than in the whites.

To test the relative precocity of the Indians, I have calculated the average age of all the Indian, Filipino, German and American children and the average number of teeth at all ages in all the groups. The ratio of the age to the number of teeth erupted in the order of precocity, is shown below:

	Age: teeth		*Age: teeth*
(1) Indian girls	100: 176.5	(5) German girls	100: 167.0
(2) Filipino girls	100: 175.0	(6) Indian boys	100: 153.6
(3) Filipino boys	100: 170.3	(7) American boys	100: 153.0
(4) American girls	100: 170.0	(8) German boys	100: 150.0

The Indian girls are the most precocious girls, and the German boys are the most backward boys. The Filipino boys are the most precocious boys, and the German girls are the most backward girls. The German boys and girls are the most backward, the American boys and girls are next to the most precocious. The girls are more precocious than the boys, but the difference is not great among the Filipinos and is greatest among the Americans.

The ratio of the groups when both sexes are combined is:

	Age: teeth		*Age: teeth*
(1) Filipinos	100: 172.6	(2) Indians	100: 165.05
(3) Americans	100: 161.5	(4) Germans	100: 158.5

The Filipinos are the most precocious, the Germans are the most backward, and the Americans and Indians are between the other two, the Indians more like the Filipinos and the Americans more like the Germans. The Indian women have a greater precocity than the Filipinos, and the Indian boys are almost exactly like the German and American boys.

Boas (6, 7, 8) and Boas and Wissler (9) have made reports as to the eruption of the permanent teeth in American whites but their work has been inaccessible to me, and what I give is based on abstracts. Boas published the following results recently with the remark that they "are not very accurate:"

TEETH	AGE IN YEARS			
	Boys		Girls	
	Boas	Bean	Boas	Bean
Inner permanent incisors	7.5	7.0	7.0	6.65
Outer permanent incisors	9.5	8.4	8.9	8.00
Bicuspids	9.8	11.1	9.0	10.6
Canines	11.2	11.6	11.3	10.5
Second molars	13.2	12.6	12.8	12.0

I do not know how the calculations were made by Boas but when compared with my results of the time when approximately 50 per cent of the teeth are erupted, his records show a retarded eruption of all the teeth except the premolars, which are precocious and erupt more than a year earlier than the premolars of the Germans and Americans of Ann Arbor. The canines in his records erupt about two years later than the 'bicuspids' (premolars?), which is very unusual. Boas and Wissler also place the end of eruption of the permanent teeth as follows: First molars, 9 years; median incisors, 12 years; bicuspids, 6 to 12 years; canines, 6 to 15 years; lateral incisors, 15 years; and second molars, 7 to 15 years. So far as I am aware, they are the only records that place the eruption of the canines after the bicuspids and the lateral incisors after both.

THE LAW OF ALTERNATION IN DEVELOPMENT

Donaldson (17–22), Jackson (32–34), Hatai (27, 28) and others have demonstrated the alternate periods of development of the parts of the body without stating a law that would apply to this phenomenon, and I have simply added to their work the results of my observations and from the combined data I have deduced a law which may be formulated tentatively somewhat as follows:

There are one or more periods of acceleration alternating with periods of retardation in the development of each structural unit or organ of the body. The periods of acceleration in the development *of one structure may be synchronous with the periods of retardation in the development of another, and the two may be called complementary structures. Each organ or structure has a critical period when it is developing most rapidly, and when it is probably most susceptible to its environment.*

Jackson determined the growth in volume of the parts of the body in relation to the whole from observations on 43 human embryos and fetuses, and other similar material. The time at which the structure attains its greatest relative size is given, but this may or may not be the time of greatest relative acceleration in growth, and it certainly is not its greatest absolute extent of growth, all of which should be considered in any study of growth.

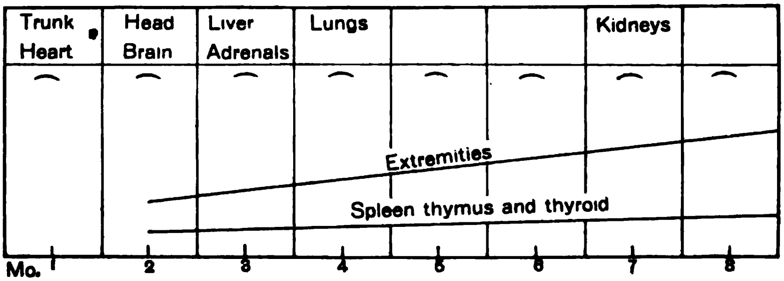

Diagram 1 Prenatal growth in man. The curved lines represent the month at which the organs named above grow most rapidly. The diagonal lines represent the approximate relative rate of growth of the organs named thereon. The number of the months is written below.

The growth of any part of the body should be determined in at least three ways. First, the amount of growth in relation to the size of the part previous to the period of growth; second, the amount of growth in relation to the adult size of the part; and third, the amount of growth of the part in relation to the total growth of the individual. The first is important because it would give the real activity of the part at different stages of its development, yet this method is not usually adopted. Diagrams 1 and 2 will serve, however, to illustrate the relative growth of the body parts.

From these diagrams it will be seen that there are three general types of growth in the white rat as demonstrated by Hatai and Donaldson: (1) represented by the brain, which is "characterized by a very rapid growth in weight at an early period and after this period the rate of growth is much reduced;" (2) represented by the extremities, spleen, thymus and thyroid which are characterized by a relatively rapid rise at an early period followed by a straight line at an angle from the base line always much greater than that of type 1; (3) represented by the sex glands, which have an irregular growth, first slow, then rapid, then slow again.

In any consideration of development it must be remembered that general laws should apply to all forms of mammals, at least, yet inasmuch as certain parts may be pathological (the brain of man is a pathological organ in relation to other forms and to evolution) any laws made for one form may not apply to another.

The first part of the white rat to develop in prenatal growth is the trunk, including the heart, spinal cord and somites, which form 65 per cent of the total body weight in the first month of intrauterine life. Next the head develops, including the brain, skull, eyeballs and face, which forms 45 per cent of the total body volume at 2 months. The extremities maintain a uniform development throughout the prenatal period after their initial rise in the second month, and so do the spleen, thymus and thyroid, although the relative growth of the last three is small compared to the relative growth of the extremities. The individual organs have a maximum relative volume during the prenatal period of growth as follows: heart, first month; brain, second month; liver, third month; lungs, fourth month; and kidneys, seventh month.

The head in man is reciprocal in its growth to the trunk, and the trunk and the parts of the extremities are reciprocal to each other and to the extremities, as demonstrated by Godin (23, 24) and Pfitzner (45, 46), therefore these parts may be called complementary structures. The development of the heart is coincident with the development of the trunk, and the development of the head is coincident with the development of the brain, therefore the heart and brain may be called complementary

BRAIN, CORD, EYEBALLS, LUNGS, SPLEEN	THYMUS, HEART, KIDNEYS, ADRENALS	STOMACH, INTESTINE, LIVER	SEX GLANDS
Rat 1st period (7 days)	2 (20 days)	3 (6 wks.)	4 (puberty)
Man 1–2 yrs.	3–5 yrs.	7–10 yrs.	puberty

Diagram 2 Postnatal growth in the white rat

structures. The development of the heart is also reciprocal to that of the lungs. The heart develops in time before the development of the brain and the lungs, but it is complementary to both. Likewise the liver may be reciprocal to the lungs, heart and brain in its development, and so each may be reciprocal to the other, but if we examine adjacent organs in their development, such as the head and trunk, the heart and lungs, and the liver and intestine, as well also as the upper and lower teeth, their reciprocal development makes them logical complements of each other.

1 STATURE	I TEETH	2 STATURE	II TEETH	3 STATURE	III TEETH	4 STATURE	SEX	IV TEETH
1–6 mos.	1–2 yrs.	5 yrs.	7 yrs.	8 yrs.	11 yrs.	12 yrs.	puberty	20 yrs.

Diagram 3 Periods of growth in stature and eruption of the teeth

The postnatal development of the structures of the white rat as given by Jackson may be grouped into four periods, and I have roughly approximated these periods for man. The brain and lungs develop most rapidly soon after birth, the heart and kidneys a little later, followed by the development of the stomach, intestine and liver. The sex glands develop irregularly but their most rapid period of development immediately precedes puberty.

I have roughly approximated the periods of most rapid growth in stature and the most rapid development of the teeth after birth, and have placed them in diagram 3. This is a tentative scheme and awaits further observations for confirmation.

The first period of postnatal growth is the most rapid of all, and is associated with the development of the trunk and extremities. This is followed by the eruption of the temporary teeth, associated with the rapid development of the brain. This reminds us of the development of the trunk in the first month of prenatal life, followed by the rapid development of the head (brain). Between the arrival of the temporary teeth and the second acceleration of growth in stature (2 to 5 years), the heart and kidneys are apparently developing most rapidly. The eruption of the first permanent teeth, followed by the third acceleration of growth in stature, is related to the most rapid postnatal development of the liver, stomach and intestine. The third period of rapid tooth development followed by the fourth period of rapid growth in stature succeeds this and precedes puberty, after which the growth of the boys is retarded and the growth of girls almost ceases. There is need of more detailed data relating to the postnatal periods of growth in stature, in the teeth, and in the other structures of the human body. Until this is forthcoming there can be no final statement as to the exact relations of these periods, but enough is known of both prenatal and postnatal development to justify the law of alternation in development.

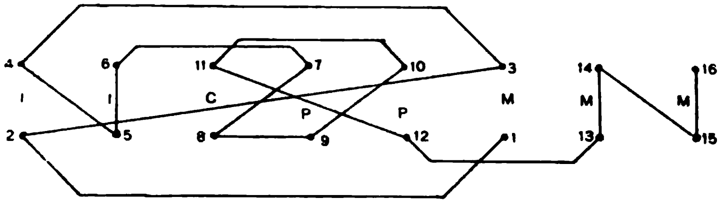

Diagram 4 The order of eruption of the permanent teeth in Europeans. One side only of the mouth is represented, the left side as viewed from in front. The dots represent the individual teeth, whose symbols are placed between them. The order of eruption of the teeth is represented by numbers and by the lines connecting the dots. *i*, incisors; *c*, canines; *p*, premolars; *m*, molars.

This law is applicable to the eruption of the individual teeth. No two adjacent teeth erupt at the same time except the median incisors, and the lower canines and median premolars. The median line represents a barrier, therefore the places filled by the median incisors are almost like remote areas. Diagram 4 represents the order of eruption of the teeth on one side of the mouth in the Germans and Americans.

The order of eruption is represented by serial numbers and followed by the line with barbs, beginning with the lower first molar and terminating with the upper third molar. The line skips from maxilla to mandible or mandible to maxilla nine times, and five times it goes from one tooth to another in the same jaw.

There are two waves of growth, one from the median line laterally, which includes the incisors, canines and premolars, 20 teeth in all, that erupt more rapidly (from 6 to 11 years) than the other wave, which includes the first, second and third molars, only 12 teeth in all, that erupt more slowly (from 6 to 20 years or later). Four molars erupt every 6 years, the first molars at 6 years of age, the second molars at 12 years of age, and the third molars at about 18 years of age. We may illustrate the two waves of growth by diagram 5, showing the relative time of development of each tooth in the two waves.

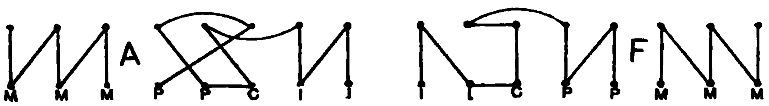

Diagram 5 The eruption of the teeth of the Filipinos and the Europeans in two series. A, American: F, Filipino. Each tooth is represented by a dot. Under the dots are symbols for the tooth; *i*, incisor; *c*, canines; *p*, premolars; *m*, molars. The order of eruption is represented by the lines.

When the permanent teeth begin to erupt the lower teeth erupt before the upper in the first period of acceleration in eruption (the first molars, incisors and canines); the upper teeth erupt before the lower in the second period of acceleration in eruption (the premolars); and the lower teeth again erupt before the upper in the final stages of eruption (the second and third molars).

The alternation in development seems to apply to abnormal as well as normal development, although insufficient data are as yet available to demonstrate this conclusively. If one structure is unusually precocious in the periods of acceleration in development its complementary structure will be backward in the periods of acceleration, and vice versa. The eruption of the teeth of the Filipino boys may illustrate this. Take the lower teeth, for instance. In the median series the median incisors are precocious, hence the lateral incisors are relatively backward, hence the canines are relatively precocious, hence the median premolars are relatively backward, and hence the lateral premolars are relatively precocious. In the lateral series the first molars are relatively precocious, hence the second molars are relatively backward, and hence the third molars are relatively precocious. The alternation is also true for the lateral series of the upper teeth where the first molars are backward, the second molars are precocious and the third molars are backward, which is not only an alternation of adjacent teeth, but also of the similar teeth of opposite jaws, because the lower first molars are precocious, and the upper first molars are backward, the lower second molars are backward and the upper second molars are precocious, and the lower third molars are precocious and the upper third molars are backward.

Racial differences in growth also fall within the law of alternation in development. It is evident from this and other studies already published or at present under way that the Filipinos mature later than the Europeans in morphologic form, especially of the face, head, nose, etc., or never reach the state of the mature European, yet the Filipinos mature earlier than the Europeans (Ann Arbor Germans and Americans) in stature and in the eruption of the teeth. Does the early development of the teeth and stature in the Filipinos cause the late maturity of the head and face, and the early development of the head and face of the European cause a late development of the teeth and stature, or are the differences incidental, or caused by other factors?

A presentation of the supposed causes of alternation in development would be incomplete without suggesting the influence of mechanical factors and the internal secretions. The alternation in development of the teeth may be produced by a more rapid growth of one tooth than another due either to an initial stimulus, or to a better blood supply. The adjacent tooth may be crowded back by the precocity of the one that develops first and the substances used in the building of the latter delay the growth of the adjacent tooth. The position or size of the blood vessels may determine the precocity of the tooth, just as the greater quantity of pure blood going to the head in the fetus may account for the early precocity of that part. There may be blood vessels to the first molars and median incisors that are larger than those to the other teeth at first, or there may be an initial stimulus to these teeth that is greater than to the other teeth. Biting and chewing in the region of the median incisors and first molars is apt to be greater at first than in the region of the other teeth. In the same way the rapid growth of the lungs soon after birth and the closure of the ductus arteriosus and foramen ovale may be explained by the shunting of the blood stream from its fetal course through the foramen ovale and ductus arteriosis to its postnatal course through the right ventricle and pulmonary artery. The activity of the lungs immediately after birth sucks the blood through the pulmonary artery and right ventricle that formerly went through the foramen ovale and the ductus arteriosus to the body, and thus allows the closure of the last two channels.

The ductless glands with their internal secretions poured into the blood stream play a part in development that is little understood, but if the normal effect of the secretions may be inferred from their abnormal effect, we may know more than we think, or understand. I cannot enter here into a review of the literature of the internal secretions, which is enormous, but I wish to present a few facts that may be relevant. We may infer from recent work that the hypophysis influences the growth of the bones, and there is some indication of the antagonistic action of the sex glands and the hypophysis, which may account for the retardation of the growth of the bones (stature) after puberty.

The growth of the sex glands is irregular after birth, according to Jackson and Hatai, and if this irregularity in their development bears any relation to the periods of acceleration in stature, we may have a causal relationship.

The thyroid influences growth, because hypothyroidism produces cretinism and hyperthyroidism produces rapid differentiation with irritability of the nervous system, when either occurs during development. A person of 13 to 14 may appear to be 20 to 25 years of age. If later in life, hypothyroidism causes simple goiter, and hyperthyroidism causes exophthalmic goiter. Exophthalmic goiter, or hyperthyroidism occurs invariably in hyperontomorphs, and cretins are hypoöntomorphs, therefore the hyperactivity of the thyroid gland may have something to do with the hypermorphism of Europeans, and the hypoactivity of the thyroid gland may have something to do with the hypomorphism of the Filipinos and other peoples (see p. 148). Climatic conditions, habits, food, water, and animal parasites may account in part for the differences.

The sexual activity of a people may have a profound effect upon their bodily form and mental condition through the interactivities of the secretions of the sexual glands and the other glands of internal secretions. A great deal more has yet to be done on the effect of the internal secretions before definite results can be assured, but the indications are that the secret of multiple activities resides in them and the explanation of many phenomena of development may be there, as well. Factors of selection, of evolution and involution, of progression or regression, of progressive metamorphosis or of retrograde metamorphosis should be mentioned here. The third molars and canines are retrograding, more in Americans than Filipinos, more in Germans than Indians.

The process of selection in evolution cannot be passed over as a factor in the eruption of the teeth. Biting and chewing, or gnawing and grinding, are the essentials in man, rather than holding and tearing, therefore the incisors and first molars develop early and are larger, and the canines develop late and are small. It is to be presumed that in prehistoric times those individuals in whom the incisors and molars developed early would be better fitted in the struggle for existence, and their kind would be propagated to a greater extent than those who had the incisors and molars developed late. The third molars are at present undergoing retrograde metamorphosis among Europeans; they appear late, and in some cases fail to appear. It is probable that the second molars erupt in man later than they once did.

The canines are also undergoing retrograde metamorphosis as indicated by their size in prehistoric times and today. The Filipinos and Indians, in whom the canines erupt early, are more like the prehistoric men than are the Germans and Americans, in whom the canines erupt late. The same is also true of the second and third molars, which also erupt earlier among the Filipinos and Indians than among the Germans and Americans.

THE MORPHOLOGIC TYPE AND THE TEETH

In a former study of Filipino students (2) I called attention to the bad teeth of what I then called the Iberian type, but have since named the hyper-onto-morph. This type is usually small, slender, narrow nosed, and has a long slender face with pointed chin, and a long narrow head with projecting occipital region, although at times the type may be fat, the face may be short and not slender, the nose may be stubby, and the head may be rounded; but at all times the type has characteristic ears, with everted anthelix, tragus and antitragus, and rolled back helix. The type is identical with the Mediterranean race of Sergi. In studies subsequent to those on the Filipino students I made observations in Manila (4), in Taytay (3), a town near Manila, and in New Orleans (5). I have demonstrated that this type is what I call an epitheliopath, a type which is very susceptible to diseases of the structures derived from epithelium, such as the lungs, alimentary canal and central nervous system. The hyper-onto-morph is quite distinct from the round-headed, round-faced type with more or less infantile nose and bowl-shaped ears. However, no observations were made of the ear form of the school children represented in this study, hence only the cephalic and facial indices, and the relative size of the occipital and parietal regions of the head can be utilized here. This will not effect a complete segregation of the hyper-onto-morph and the hypo-onto-morph, but it will indicate that a complete segregation such as might be accomplished by the use of the ear form and other factors would give a more marked contrast between the two types in the eruption of the teeth, in the number of good sets present, and in the average number of bad teeth. As it is, the segregation by cephalic and facial indices gives considerable difference in all three of these conditions.

The two types are segregated by putting those with a cephalic index below 80 and a facial index below 120 in one group, and those with a cephalic index of 80 and over and a facial index of 120 and over in another, and the remainder, or those with a cephalic index of 80 and over and a facial index of 120 and less, or those with a cephalic index of 80 and less and a facial index of 120 and over, in a third group. The three will be called the hyper-onto-morph, hypo-onto-morph and remainder. Below the age of 11 years the dividing figure of the cephalic index is 81 instead of 80.

1. The average number of teeth

The Filipinos from 5 to 10 years of age may be neglected because of the few individuals who come under observation. The average number of teeth erupted among the German and American boys from 5 to 10 years of age is

Hyper 9.87 Hypo 9.14 Remainder 9.45

The average number of teeth erupted in all the groups from 11 to 16 years of age, including both sexes, is

Hyper 26.6 Hypo 24.1 Remainder 25.4

The hyper- is more precocious than the hypo- from 10 to 16 years of age. It is therefore evident that the hyper-, at all ages, is more precocious in the eruption of the permanent teeth than the hypo-, and this difference amounts to one or more teeth.

2. The percentage of good sets of teeth

The percentage of good sets of teeth among the German and American boys and girls from 5 to 10 years of age is

Hyper 80.33 Hypo 80.98 Remainder 82.8

The percentage of good sets of teeth among the boys and girls of all the groups from 11 to 16 years is

Hyper 18.3	Hypo 46.8	Remainder 34.4

Among the Filipinos alone from the age of 17 to 30, both sexes, it is

Hyper 9.3	Hypo 34.3	Remainder 24.2

It is evident that the hyper- has fewer good sets of teeth at all ages than the hypo-.

3. The average number of bad teeth

The Filipinos below the age of 10 years may be disregarded. The average number of bad teeth below the age of 10 years among the German and American boys and girls is

Hyper 0.468	Hypo 0.36	Remainder 0.30

The average number of decayed teeth in all the groups from 11 to 16 years of age is

Hyper 3.35	Hypo 1.79	Remainder 2.09

The average number of decayed teeth among the Filipinos alone from 17 to 30 years of age is

Hyper 3.33	Hypo 2.53	Remainder 3.08

It is evident from a consideration of the average number of bad permanent teeth that the hyper-s have the worst teeth and the hypo-s have the best.

4. Racial and sexual differences

Racial differences may be found by calculating the relative number of hyper- and hypo- individuals in each group. Between the ages of 5 and 16 the Filipinos have 1 hyper- to 15.2 hypo-s, the Germans have 1 hyper- to 5.3 hypo-s, and the Americans have 1 hyper- to 1 hypo-. From 17 to 30 years the Filipinos have 1 hyper- to 3.8 hypo-s.

Sexual differences may be determined in the same manner. The Filipino girls have 1 hyper- to 28 hypo-s; and the Filipino boys have 1 hyper- to 4.6 hypo-s; the German girls have 1 hyper- to 7.1 hypo-s, and the German boys have 1 hyper- to 4.3 hypo-s; and the American girls have 1 hyper- to 1.2 hypo-s, and the American boys have 1 hyper- to 0.84 hypo-.

It is also noticed that the relative number of hyper-s increases with age. This is especially noticeable with the American boys for whom the ratio is 1 hyper- to 3 hypo-s at 8 years of age, and 12 hyper-s to 1 hypo- at 16 years of age.

Hyper-morphism is a condition, of greater age, of development in a certain direction, a male condition, and a condition characteristic of the American white. Hypo-morphism is a condition of less age, of development in another direction, a female condition, and a condition characteristic of the Filipino.

A number of other conditions besides the shape of the head and face characterize the hyper- and the hypo- types, such as the shape of the nose, the relative length of the extremities and of their parts, the ear form, the size of the regions of the head, etc., but it will suffice to give only one of these here, that is, the relative size of the occipital and parietal regions of the head.

The circumferences of the forehead, frontal, parietal and occipital regions of the head of the school children were taken but they will be reserved for future studies of head form that are at present under way, only the relative size of the occipital and parietal regions of the head to each other will be given here.

The points selected from which to measure the circumferences of the regions of the head are the dorsal extremities of the middle roots of the zygoma on each side of the head immediately ventral to the external ear, a place that is easily accessible and distinctly felt. The tape was passed from the point on the right side to the point on the left side around the maximum protuberance of the parietal and occipital regions of the head, and this distance recorded as the circumference of the part. An index is obtained that is called the occipito-parietal index, by multiplying the occipital circumference by 100 and dividing by the parietal circumference. This gives the occipital circumference in terms of the parietal, the latter always being 100. A high index denotes a large occipital region, a low index the reverse.

The occipito-parietal index in the German and American children from 5 to 10 years of age is

Hyper 80.9	Hypo 79.9

and from 11 to 16 years of age is

Hyper 82.2	Hypo 79.4

The occipito-parietal index in the Filipino boys is

5 to 10 years	Hyper 88.4 (1)	Hypo 78.3
11 to 16 years	Hyper 81.9	Hypo 76.7
17 to 30 years	Hyper 83.4	Hypo 79.9

The index of the Filipinos is less than that of the Germans and Americans at the same age, and the index of the hypo- in the Filipino from 17 to 30 years of age has reached that of the Germans and Americans at the age of 5 to 10 years, but the index of the hyper- among the Filipinos at 17 to 30 years of age has passed that of the Germans and Americans at the age of 11 to 16. The index increases with age except that the hypo-s among the Germans and Americans do not change.

The hypo- has a relatively smaller occipital region in the Filipino than in the German, and a relatively larger occipital region in the American than in the German. The same is not true for the hyper-, for in them the occipital region is about the same for the American and Filipino, but relatively smaller for the German.

The sexual differences indicate that the male has a relatively larger occipital region than the female, and the female a relatively larger parietal region than the male although the difference is not great.

No other differences will be presented here, although differences in stature, weight, nose form, ear form, facial angle, cranio-facial index, etc., will be given in subsequent publications, but enough has been done to establish the hyper-onto-morph and the hypo-onto-morph as entities and to indicate their identity.

Magitot (37) called attention to the differences in the decay of the teeth in Normandy and Brittany, and attributed the difference to the type of people in the two compartments of France. In Brittany are the Celts or Gauls, who are small, with dark hair and eyes, broad head, and with good teeth; in Normandy are the Belgians or Kymries, who are tall, with fair hair and eyes, long head, and with bad teeth. The color of hair and eyes seems to be incidental, because in those I examined with bad teeth and of hyper-onto-morph form, the color of hair and eyes was of all shades. In southern Europe the long head has dark hair and eyes and in northern Europe fair hair and eyes, and in central Europe the broad head has dark hair and eyes and in eastern Europe the same form has fair hair and eyes. The morphologic type is independent of pigmentation and I believe the time of eruption of the permanent teeth and the extent of their decay are due to inherent differences in the morphologic type of the individual.

The teeth of the hyper- form are undergoing retrograde metamorphosis because they appear early and decay early. It is believed that the third molar in man is undergoing retrograde metamorphosis more rapidly than the other teeth and there are indications that the canines are also undergoing rapid retrograde metamorphosis, because the canines appear late and the third molars sometimes do not appear at all. It is strange to say that the teeth of the hyper- are undergoing retrograde metamorphosis because they appear early and decay early and the canines and molars are undergoing retrograde metamorphosis because they appear late or not at all, yet such is the inference. In the case of the hyper- there is rapid differentiation with early decay and in the canines and premolars retardation or failure to appear through backwardness. Retrograde metamorphosis, as in the human ear, seems to come about with precocity, involution probably occurring earlier and earlier with each succeeding generation, therefore the hyper- is a very much involved form. Involution in the teeth may occur in the same way until crowding causes the third molars and canines to appear late and finally to fail to appear. There may also be more than one method of evolution.

The hypo- and hyper- are both undergoing retrograde metamorphosis, the hyper- in America, the hypo- in Asia, and the Meso form carries the evolution for the future.

It is noted that the Filipinos are more precocious than the Americans in the eruption of the permanent teeth, although the Filipinos are more hypo- than the Americans, and the hypo- is more backward than the hyper- in this respect. Therefore the precocity of the Filipinos must be attributed to something other than hypermorphism. Whether it is race, climate, food, water, animal parasites, or something else, is problematic.

PHYSIOLOGICAL STANDARD

Each tooth may be considered from the standpoint of the time at which it first appears in any individual, and the time at which it last appears in any individual, as well as from the time at which 50 per cent of the individuals have the tooth erupted, and the time during which the greatest number of individuals have the tooth erupting. Suppose we take the left upper second molar tooth in the American girls. This tooth has not erupted in any American girl at 9 years of age, but 2 per cent appear at 10 years, and the latest age at which any erupt is 15 years, all are erupted at 16 years. Approximately 50 per cent have the tooth erupted at 12 years, therefore there is a shorter period for the eruption of the first 50 per cent (10 to 12 years), than for the eruption of the second 50 per cent (12 to 15 years). The greatest number of teeth erupt between 11 and 12 years (41 per cent) although there is a second period of rapid eruption between 13 and 14 years. This may be a segregation of the precocious and backward American girls.

In like manner we may obtain the same data for all the other teeth of the American girls, and of the teeth of all the other boys and girls. The upper teeth of the same type on the two sides, as the upper median incisors, erupt at so nearly the same time that they may be put together. The periods of most rapid eruption almost invariably coincides with the time at which 50 per cent of the teeth have erupted therefore the limits of the first mentioned period will cover the second. Table 1 (p. 155) has been constructed showing the results, and this table will be the physiological standard for each group of individuals in relation to the eruption of each tooth. The ages given are the ages at which the teeth normally appear. If the teeth appear earlier in any individual, that individual is precocious, and if later, backward.

The physiological standard may be utilized to greater advantage with increasing age, because the racial and sexual differences increase with age. A word as to one way in which such a table may be of use. Take a German girl of 10 years, and all the incisor teeth, the first molars, premolars and canines may be erupted, whereas a German boy may not have all these teeth erupted until 11 years of age, yet at 11 years he may be at the same physiological standard as the girl at 10 years. Should either one have all the teeth mentioned erupted at the age specified there would be evident precocity. In like manner evident backwardness may be determined.

The teeth are more convenient and more exact as a means of determining the physiological standard than stature, or weight, or the growth of the bones, or secondary sexual characters, etc., and they *may* be of greater value than any other means that can be utilized. The teeth can be seen, recognized and counted by almost anyone after a little experience, and they are either present or absent, therefore very definite.

Precocity in the eruption of the permanent teeth is a sign of hyper-morphism, and hyper-onto-morphs are epitheliopaths, who are especially susceptible to diseases of the alimentary canal, the lungs and the central nervous system, therefore precocious children should be shielded from injuries to the susceptible organs.

Backwardness in the eruption of the permanent teeth is a sign of hypo-morphism, and hypomorphs should be shielded from injuries to their susceptible organs.

THE SCHOOL GRADE AND THE TEETH

The modal grade, or the grade that has the greatest number of individuals at each age, varies little with sex but the Germans are about one year behind the Americans. This corresponds with the backwardness of the Germans in the eruption of the permanent teeth, and indicates a correlation of mental and dental development. This is true not only of the modal grade, but also of the grades above and below the mode. At each age, from 7 to 14 inclusive, the children who are below the modal grade have an average of 0.9 of a tooth less than those in the modal grade, and the children who are above the modal grade have an average of 0.8 of a tooth more than those in the modal grade. The difference is greatest at 10 and 11 years, when the second period of the second dentition is at its height, and the difference at these two years amounts to 1.5 fewer and 1.8 more teeth for those below and above the mode respectively.

It will be recalled that there is a period of one year during which the greater number of teeth of any form erupt, and during this year in nearly every case, 50 per cent of that form of tooth has erupted. From this a physiological standard, or age of eruption of each tooth, was determined. Evidence is therefore produced to indicate that the eruption of the teeth is a better criterion than age as a standard of both physical and mental development.

This evidence is not conclusive for each individual, but only as an average or modal factor, because some individuals with fewer teeth than normal are above the modal grade, and some individuals with more teeth than normal are below the modal grade. Other factors therefore play a part and must not be overlooked. For instance, one child who was advanced in school grade beyond her age, and who had less than the normal number of teeth present, was the child of a teacher, and had evidently been pushed in school work. However, the condition of the teeth, both as to eruption and decay, may be utilized and may be of value in determining the relative development of the individual.

Maturity in the Filipinos is different from maturity in the Europeans, at least the face, body form, extremities, etc., of the Filipinos differ from the same parts in the Europeans, and the time of definite maturity of the parts is different. Each people is probably an expression of different conditions, and each represents development in a different direction, at a different rate, and to a different extent. The adult Filipino resembles the infant European in morphologic type more than it does the adult

European. The condition of the Filipino in stature and in the eruption of the permanent teeth seems to be an early precocity superseded by an early retardation in development, but in morphologic type the Filipino is retarded throughout the period of development.

RÉSUMÉ

1. The eruption of the teeth in relation to the development of the individual: the physiological standard

The time of most rapid eruption of the teeth and the time at which 50 per cent have erupted is the same, and may be called the physiological standard of the teeth. This is shown in table 1, for the Americans, Germans, and Filipinos.

TABLE 1

	GIRLS, AMERICAN AND GERMAN,	BOYS, AMERICAN AND GERMAN,	FILIPINOS,
FIRST MOLARS	6 YEARS	6.5 YEARS	5? YEARS
Median incisors	6.5	7.0	5?
Lateral incisors	8.0	8.5	6?
Median premolars	10.0	11.0	8.0
Canines	10.5	11.5	7.0
Lateral premolars	10.0	11.5	9.0
Second molars	11.5	12.5	10.5

2. The eruption of the teeth in relation to stature: periods of rapid development

TABLE 2

	1 PERIOD	2 PERIOD	3 PERIOD	4 PERIOD
Boys' stature	1–6 mos.	3–5 years	7–9 years	12–14 years
Boys' teeth	6 mos.–2 yrs.	6–9 years	10–13 years	
Girls' stature	1–6 mos.	2–4 years	6.5–7.5 years	10–14 years
Girls' teeth	6 mos.–2 yrs.	6–8 years	9–11 years	

3. The eruption of the teeth in relation to race

The American white is taken as the standard. Order of eruption: (1) Filipino, (2) French, (3) American Indian, (4) American white, (5) German. The time at which 50 per cent of the teeth have erupted: French 6 months to 1 year earlier than American white. German 6 months to 2 years later than American white. American Indian is from 1 to 6 months earlier than the American white. Filipino 1 to 4 years earlier than American white.

4. The eruption of the teeth in relation to sex

American girls are from 0.2 years for the incisors, to 1.4 years for the canines, earlier than the American boys. German girls are from 0.3 years for the incisors to 1.1 years for the canines, earlier than the German boys. Filipino girls and boys are more nearly alike in the time of eruption.

5. The eruption of the teeth in relation to school grade

The modal grade is the grade which has the greatest number of individuals at each age. For instance at 7 years of age the second grade is the modal grade. At ages 7 to 14 inclusive, children above the modal grade have 0.8 more teeth, and children below the modal grade have 0.9 fewer teeth, than children at the modal grade. The difference is greatest at 10 and 11 years, i.e., during the most rapid eruption of the second part of the period of second dentition, when children above the modal grade have 1.8 more teeth, and children below the modal grade have 1.5 fewer teeth, than children at the modal grade.

6. The eruption and decay of the teeth in relation to morphologic form

Two types, extremes: (1) Hypo- equals infantile, round head, broad face and nose, large parietal and small occipital region of head. (2) Hyper- equals long head, face, nose, small parietal, large occipital region of the head (table 3):

TABLE 3

Teeth erupted:			
Below 10 years	Hyper, 9.87	Hypo, 9.14	German and American
Above 10 years	Hyper, 26.6	Hypo, 24.1	
Good sets:			
Below 10 years	Hyper, 80.3 %	Hypo, 81 %	German and American
Above 10 years	Hyper, 18.3 %	Hypo, 46.8 %	
17–30 years	Hyper, 9.3	Hypo, 34.3	Filipino
	Average number of decayed teeth		
Below 10 years	Hyper, 0.47	Hypo, 0.36	German and American
Above 10 years	Hyper, 3.35	Hypo, 1.8	
17–30 years	Hyper, 3.33	Hypo, 2.53	Filipino

Characteristics of the individuals in each group:

	5–16 years		17–30 years		Girls		Boys	
	Hyper,	Hypo	Hyper,	Hypo	Hyper,	Hypo	Hyper	Hypo
Filipinos	1	15.2	1	3.8	1	28.0	1	4.6
Germans	1	5.3			1	7.1	1	4.3
Americans	1	1.0			1	1.2	1	0.84

American boys have 1 hyper- to 3 hypo-s at 8 years, and 12 hyper-s to 1 hypo- at 16 years.

7. *The law of alternation of development*

There are one or more periods of acceleration alternating with periods of retardation in the development of the structures of the body. Each organ or structure has a critical period when it is developing most rapidly, and when it is probably most susceptible to its environment. The periods of acceleration in the development of one structure are synchronous with the periods of retardation in the development of another, and the two may be called complementary structures.

The relative number of hyper-onto-morphs is greatest among the Americans, least among the Filipinos, and nearly as great among the Germans as among the Americans. Hypo-morphism decreases with age, and hyper-morphism increases, so that whereas among the Filipinos there are 15.2 hypo-s to 1 hyper- between the ages of 5 and 16, there are only 3.8 hypo-s to 1 hyper- from 16 to 30 years of age. Hypo-morphism is a condition of less maturity than hyper-morphism. Apparently the Filipinos mature more slowly than the Americans and Germans in morphologic form, although they mature earlier in stature and in the eruption of their permanent teeth, which, again, may be only another expression of compensation in the law of alternation in development.

The teeth are useful as a physiological standard for determining the relative development of the individual, physically and mentally.

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A RACIAL PECULIARITY IN THE POLE OF THE TEMPORAL LOBE OF THE NEGRO BRAIN

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NINETEEN FIGURES (THREE PLATES)

While at the University of Michigan in 1906, I examined some casts of the interior of skulls which I had made in the Anatomical Laboratory of the Johns Hopkins University. My attention was struck by the apparently small size of the pole of the temporal lobe of the negro brain as compared with that of the white; and, proceeding to apply the calipers, the difference was demonstrated to be a measurable quantity. I then measured some brains from whites in the Anatomical Laboratory of the University of Michigan and others from both whites and negroes in the Anatomical Laboratory of the Johns Hopkins University, and at The Wistar Institute. I wish to thank Dr. McMurrich, Dr. Mall and Dr. Greenman for permission to use the material in their charge and for assistance in the work of making measurements.

MATERIAL AND METHODS

The material studied consisted of 127 brains of negro males, 53 of negro females and 53 of white males (no white females) and measurements were made on each temporal lobe in two planes. The two planes selected are called basal and pole. For the basal plane I selected a plane passing horizontally through the temporal lobe, beginning posteriorly on the inferior surface at a point where a shallow depression is found in the inferior lateral border of the lobe by the upward projection of the petrous portion of the temporal bone, and ending anteriorly at a line where, if the plane were extended, it would leave the temporal lobe to pass along the lowest part of the orbital surface of the frontal lobe. A straight-edged ruler laid alongside the brain will indicate the plane, if the edge of the ruler is on a level with the lower border of the frontal lobe and the depression in the temporal lobe made by the petrous bone.

The other or pole plane selected was parallel to the first and through a point 5 mm. vertically above the lowest projecting point of the temporal lobe. The two planes were measured both in their antero-posterior and transverse diameters.

The planes selected are not always the same in the brains examined, but they are the best that could be located and the results bear out the evidences of inspection of brains, and of skull casts, as well as of photographs of these and the evidences of Hrdlička's measurements of the skull. Therefore they are dependable if only as an approximation of the condition. The measurements cover only a small part of the temporal lobe, and that the mere extremity.

It may be added that in calculating the standard deviation, skewness of the curve and probable errors, Pearson's methods or Davenport's formulae have been followed. The median has been used instead of the mean because of the small number of individual measurements, the ease of calculation and the almost exact identity of the two.

MEASUREMENTS IN THE BASAL PLANE

The antero-posterior diameter of the basal plane shows the white males congregated about 52 to 56 mm., the negro males about 50 to 54 mm., and the negro females about 48 to 52 mm. The mean, that is to say the point midway between the most extreme cases, is 54 mm. for the whites, 52 mm. for the negro males and 48 mm. for the negro females. The median, that is to say the point with an equal number of cases on either side, is 54.3 mm. for the white males, 51.5 mm. for the negro males and 49.25 mm. for the negro females, while the extremes are separated by 26 mm. in the white males and in the negro males, but by only 22 mm. in the negro females. The averages of the antero-posterior diameter of the basal plane of the three groups are 54.7 mm. for the white males. 51.8 mm. for the negro males and 49.4 mm. for the negro females and the mode is 55 mm. for the white males, 52 mm. for the negro males and 50 mm. for the negro females.

From these figures it will be seen that the antero-posterior diameter of the basal plane of the temporal lobe is greater in the white males than in the negro males and greater in the negro males than in the negro females, in the mean, on the average and by the median and the mode, the difference being about 3 mm. between the white males and the negro males and about 2 mm. between the negro males and females.

Hrdlička has measured the antero-posterior diameters of the fossae of the skull in various races, both in adult individuals and young, and in monkeys and other animals, and has determined that the temporal or middle fossa of the negro skull is absolutely shorter than that of the white or that of the Indian, and that it is also shorter in proportion to the total external length of the skull, this being especially noticeable in dolichocephals. His results are based on measurements of 55 negro skulls, male and female, compared with those of 90 white skulls, male and female, and those of the skulls of 20 Indian males. Although the points and planes selected are not exactly the same as those I used, yet there is no very great difference between his and mine, and the results of the two sets of measurements, the one on the skull and the other on the brain, are corroborative.

As regards the transverse diameter of the basal plane, the white males are grouped around 48 to 50 mm., the black males around 42 to 46 and the black females around 44 to 46. The mean is 49 mm. for the white male, 42 mm. for the negro male and 44 mm. for the negro female, and the median is 49 for the white male and 44 for both the male and female negro. The extremes are separated by 14 mm. in the white male, by 22 mm. in the black male and by 18 mm. in the black female. The averages are 49.3 mm. for the white male, 44.4 mm. for the negro male and 44.5 mm. for the negro female; and the mode is 50 mm. for the white male, 46 mm. for the negro male and 44 mm. for the negro female.

The transverse diameter of the temporal lobe in the basal plane is accordingly greater in the white male than in the negro male by about 5 mm. and it is about the same size in the two sexes of the negro, in the mean and in the average, by the median and by the mode. A comparison will show that there is a greater racial difference between the two sets of males in this, the transverse, diameter of the basal plane than in the antero-posterior one. Taking the averages, the difference between the two diameters in the white male brain is 54.7 minus 49.3 equals 5.4 mm., while that in the negro male brain is 51.8 minus 44.4 equals 7.4 mm., the transverse diameter of the basal plane as compared with the antero-posterior diameter being thus 2 mm. less in the negro male than in the white male, or, conversely, the antero-posterior diameter relatively to the transverse is 2 mm. greater in the negro male than in the white male. This difference may, perhaps, be better expressed by representing the relation by an antero-posterior transverse index in which the transverse diameter is taken as 100. Then the index for the male white is 110.9, while that for the male negro is 116.4. The difference between the averages of the diameters in the negro female is 4.9 mm., differing from that of the white male by 0.5 mm., while the index is 111, almost identical with that of the white male.

Hrdlička has measured the pituitary fossa in negro and white skulls, but his measurements do not extend to the body of the sphenoid bone and hence cannot be used for comparison.

MEASUREMENTS OF THE POLE PLANE

The measurements made at 5 mm. from the lowest projecting point of the temporal lobe are necessarily less accurate than those of the other two planes on account of the greater difficulty of obtaining the exact location of the plane, the variable shape of the temporal pole, etc. There is, however, an appreciable racial difference. The modes of the white males are about 26 mm. and about 34 mm.; those of the black males about 22 mm. and about 28 mm.; and those of the black females about 16 mm., about 20 mm. and about 26 mm. This multiple grouping is due to the different shapes of the temporal pole, some being long, others round, while others are oval or oblong. These various shapes occur in each race-sex group and hence do not interfere with a fair comparison.

The transverse diameter of the pole plane is more homogeneous than the antero-posterior. The white males are grouped about 24 mm. and the negro males and females about 18 mm. The numbers of about the same value are more extensive than in the other arrays, indicating a tendency to a large grouping about the mode. A curve to illustrate this would be platycurtic, or flat-topped (McDonnell). The transverse diameter of the pole plane passes below the hippocampus.

THE SIZE OF THE TEMPORAL LOBE RELATIVE TO THE BRAIN WEIGHT AND SIZE

A comparison of the size of the temporal lobes with the total brain weights was made in the brains of 34 negro males, 21 negro females and 13 white males, and the results showed that there was a slight increase in the size of the temporal lobe with increase of brain weight, and that this increase was greatest in the white males and greater in the negro female than in the male. The brain weight of the white is greater than that of the negro and this might possibly account for the difference in the size of the temporal lobes as already determined. But this indicates that the lobes of the white are larger absolutely and relatively to brain weight, than those of the negro.

The same result is obtained by a comparison of the diameters of the temporal lobes with the diameters of the cerebral hemispheres to which they belong, length with length and breadth with breadth.

It will be seen that both in series and by averages the white has the advantage of the negro, the dimensions of the temporal lobes are actually greater in the white except in the case of the antero-posterior diameter of the basal plane, where the negro female has an advantage of 1 mm. in the average over the white male and of 2.6 mm. over the negro male.

CONCLUSIONS

The general conclusions may be stated concisely as follows:

1. The size of the pole of the temporal lobe is less in the negro than in the white, and less in the negro female than in the male.

2. The differences are more pronounced in measurements taken below the hippocampus than in those which pass through that structure. Hence it is probable that

3. The hippocampus is larger in the negro than in the white and larger in the negro female than in the male.

4. The shape of the pole of the temporal lobe is different in the two races, being slightly more slender in the negro, and almost the same size in the two races antero-posteriorly

5. The differences are not only absolute but are also relative to the weight and size of the entire cerebral hemispheres.

The brains collected at Tulane University confirm the evidence in relation to the temporal lobe of the brains examined at the University of Michigan, at The Wistar Institute, and at the Johns Hopkins University. The brains examined at Tulane University were preserved in a uniform manner, but the brains examined in the other places were not, and the differences noted at Tulane University are more distinct than elsewhere.

NOTE CONCERNING RECENT OBSERVATIONS ON THE NEGRO BRAIN

The brains examined here were preserved in the following manner: The bodies from which the brains were removed were injected with the usual Souchon solution as soon after death as possible, usually at least twenty-four hours after, and they were allowed to remain another twenty-four hours before the brains were removed. The skull caps were sawed as low down over the forehead and occipital region as practicable to remove the cap without disturbing the brain, and after the removal of the brain it was weighed and placed in 10 per cent formalin solution, base up, fitting it into the skull cap. The brains were found to harden readily, and to retain their shape especially well in the region of the temporal lobes. The skull cap being the shape of the vertex this also retains its shape. Should the brain be soft it may spread a little over the cut sides of the skull cap, but if the brains are fitted well into the skull cap this seldom occurs.

In a test of the accuracy of my powers of observation, nine brains were selected at random without knowing their race character, and from the temporal lobes alone I judged the race correctly in all except two, which I called white, whereas they were from light-skinned mulattoes.

The brains have been measured in various dimensions, and observations as to the size of the pons, cerebellum, convolutions, etc., have been made, but these are reserved for future publication.

The temporal lobe of the brain may be described better than it can be measured. The upper part of the lateral side of the lobe in the negro brain is flat and the lateral side is also flat as it turns downward, inward and forward straight to the tip or pole of the lobe. In the white brain the upper part of the lateral side of the lobe is round, and the lateral side is also round and instead of passing downward as a flat surface it makes a graceful rounded sweep inward to the pole of the lobe.

The medial surface of the temporal lobe is almost perpendicular in the white brain, but in the negro it slopes outward. This makes the temporal lobe of the white brain appear to turn inward at the pole, whereas in the negro brain it is directed downward.

The pole of the temporal lobe is more slender, smaller and narrower in the negro than in the white brain.

The temporal pole of the brain of the negro female is more like that of the white than is the brain of the negro male, especially on the lateral surface, and this is due to the rounded surface of the female negro brain and the angular surface of the male negro brain.

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PLATE 1

EXPLANATION OF FIGURES

1 Skull casts; side view. Note the narrow pole of the temporal lobe in the negro skull cast.

White male	*White male*	*White male*	*Negro male*	*Negro male*
1245	1245	1216	1582	1582
Dura	Dura	No dura	Dura	Dura

The numbers refer to the serial number of brains (subjects) at the Johns Hopkins Anatomical Laboratory.

2 Skull casts; view from below. Note the wide pole of the temporal lobe in the white skull cast; note also the great width of the space between the poles in the negro casts.

Negro male	*Negro male*	*White male*	*Negro male*	*Negro male*
1247	1330	1216	1212	1217
Dura	Dura	No dura	No dura	No dura

3 Brains; view from below. Note the narrow poles of the temporal lobes of the negro brain and cast and the wide space between them.

White brain	*White brain*	*Negro brain*	*White brain*	*Skull cast*
Ann Arbor	Ann Arbor	Ann Arbor	Ann Arbor	Negro male
				1212
				No dura

4 Skull casts; front view. Note the narrow temporal poles and the wide space between them in the negro skull casts.

Negro male	*Negro male*	*White male*	*Negro male*	*Negro male*
1219	1217	1216	1330	1247
Dura	No dura	No dura	Dura	Dura

PLATE 2

EXPLANATION OF FIGURES

The outlines in figures 5 to 19 inclusive were made from projections through a lens with the brains each at the same focal distance from the lens. The gyri and sulci of the temporal lobes are given, as only these are in focus. The outlines show the temporal lobes as if viewed from above through transparent brain substance.

5 Brain 2; white male; age 25; cause of death, pulmonary tuberculosis. Total brain length, right hemisphere 16 cm.; left hemisphere 16 cm.; total brain breadth 14 cm.; total brain height 10.1 cm. weigh 1304 grams. Note the wide temporal lobes.

6 Brain 1; negro male, age 65; cause of death, nephritis. Total brain length, right hemisphere 17 cm.; left hemisphere 17.2 cm.; total brain breadth 14 cm. Weight 1361 grams. Note the narrow temporal lobes.

7 Brain 6; white male; age 55; cause of death, pulmonary tuberculosis. Total brain length, right hemisphere 16.2 cm.; left hemisphere 16.5 cm.; total brain breadth 14 cm.; total brain height 10.4 cm. Weight 1332 grams. Note the wide temporal lobes.

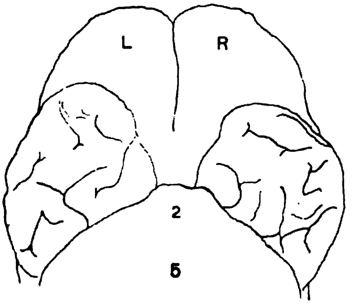
8 Brain 8; negro male; age 48; cause of death, tuberculosis. Total brain length, right hemisphere 16.7 cm.; left hemisphere 16.8 cm.; total brain breadth 13.6 cm. Weight 1503 grams. Note the narrow temporal lobes.

9 Brain 7; negro female; age 75; cause of death, unknown. Total brain length, right hemisphere 16.1 cm.; left hemisphere 16.1 cm.; total brain breadth 12.4 cm. Weight 992 grams. Note narrow tips of the temporal lobes.

10 Brain 10; white female; age 23; cause of death, lobar pneumonia. Total brain length, right hemisphere 15.5 cm.; left hemisphere 15.7 cm.; total brain breadth 12.6 cm.; total brain height 10.6 cm. Weight 1155 grams. Note the wide temporal lobes.

11 Brain 9; negro male; age 38; cause of death, pulmonary tuberculosis. Total brain length, right hemisphere 16.5 cm.; left hemisphere 16.4 cm.; total brain breadth 13.5 cm.; total brain height 10.6 cm. Weight 1304 grams. Note the narrow poles of the temporal lobes.

12 Brain 3; mulatto male; age 53; cause of death, nephritis. Total brain length, right hemisphere 16.8 cm.; left hemisphere 17 cm.; total brain breadth 13.6 cm. Weight 1389 grams. Note the wide temporal lobes like those of the white.



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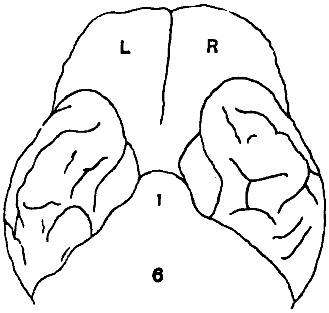

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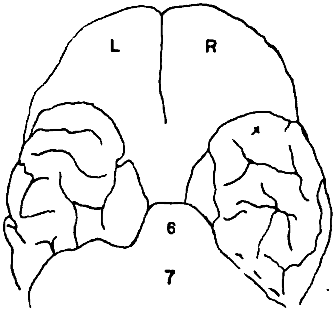

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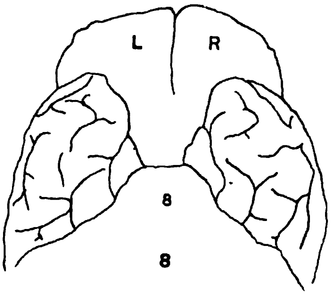

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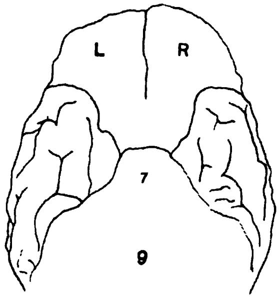

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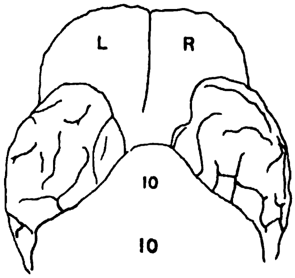

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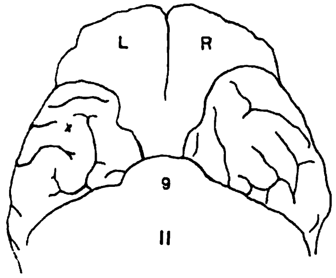

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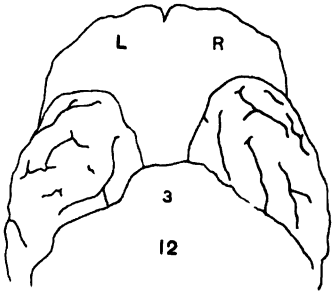


12

PLATE 3

EXPLANATION OF FIGURES

13 Brain 14; negro male; age 38; cause of death,. pulmonary tuberculosis. Total brain length; right hemisphere 15.8 cm.; left hemisphere 15.6 cm.; total brain breadth 12.1 cm.; total brain height 9.9 cm. Weight 1106 grams. Note the narrow temporal lobes.

14 Brain 4; negro male; age 65; cause of death, nephritis. Total brain length, right hemisphere 16.7 cm.; left hemisphere 16.7 cm.; total brain breadth 12.1 cm. Weight 1219 grams. Note the narrow temporal lobes.

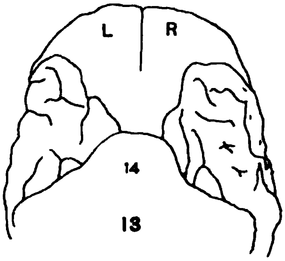
15 Brain 12; negro female, age 70; cause of death, arterio-sclerosis. Total brain length, right hemisphere 16.3 cm.; left hemisphere 16.7 cm.; total brain breadth 12.3 cm.; total brain height 10.9 cm. Weight 1169 grams. Note the narrow points of the temporal lobes.

16 Brain 11; mulatto female; age 24; cause of death, pulmonary and intestinal tuberculosis. Total brain length, right hemisphere 17 cm. (distorted; left hemisphere 16.4 cm.; total brain breadth 12.8 cm. Weight 1155 grams. The temporal lobes are as wide as in the white.

17 Brain 15; negro male; age 28; cause of death, lobar pneumonia. Total brain length, right hemisphere 17.1 cm.; left hemisphere 17.1 cm.; total brain breadth 12.7 cm. Weight 1304 grams. Note the narrow point of the temporal lobes and the large hippocampus.

18 Brain 13; negro female; age 23; cause of death, pulmonary tuberculosis. Total brain length, right hemisphere 16.6 cm.; left hemisphere 16.4 cm.; total brain breadth 12.7 cm. Weight 1219 grams. Note the narrow point of the temporal lobes and the large hippocampus.

19 Brain 5; mulatto male; age 39, cause of death, lobar pneumonia. Total brain length, right hemisphere 16.8 cm.; left hemisphere 16.8 cm.; total brain breadth 12 cm. Weight 1233 grams. The temporal lobe is wide as in the white.



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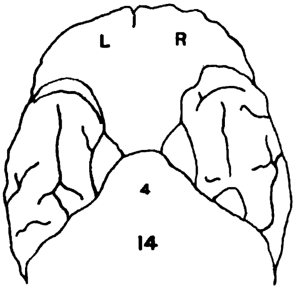

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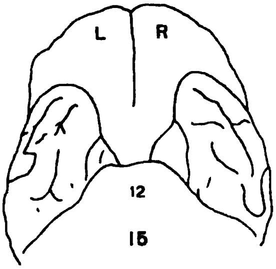

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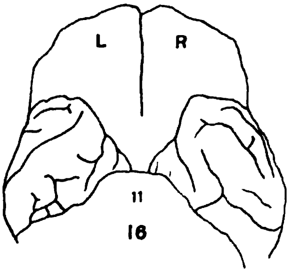

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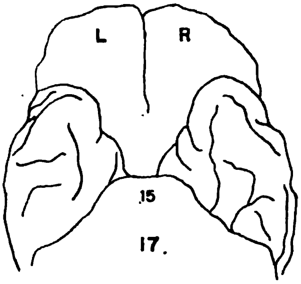

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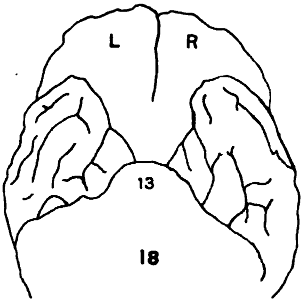

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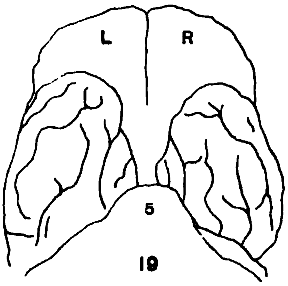


19

THE ERUPTION OF THE TEETH AS A PHYSIOLOGICAL STANDARD FOR TESTING DEVELOPMENT

By Robert Bennett Bean,
The Anatomical Laboratory, the Tulane University of Louisiana

The data:	630	Filipino boys	776
	146	Filipino girls	
	322	German boys	628
	306	German girls	
	407	American boys	817
	410	American girls	
			2,221

Materials

During the school term of 1906-07 I examined and measured every available child in the public schools of Ann Arbor. This was made possible through the coöperation of Dr. McMurrich, the superintendent of schools, and the teachers, who showed commendable zeal in furthering the work. The teeth of the children were examined by Dr. Bunting who also assisted me in making the records. Two groups of children were segregated, the one of American parentage solely, the other of German, or American and German parentage. The titles American and German will be used for the two groups. When taken together the German and American children will be called European. Children were grouped as German if two grandparents or if either parent came from Germany and whenever the name was German and the parentage was not given the child was included in the German group, although there were only a few records of this kind. There is a large colony of Germans both in the town of Ann Arbor and in the adjacent country and the majority of the Germans included in the records are of pure German extraction. A large number of children of the teaching staff at the University of Michigan are included in the American group and a large number of rural children are included in the German group. The whole lot of children may be called sub-urban.

The Manila school children were examined by myself in 1907-08 at the Normal and Trade schools, where pupils from all parts of the Philippine Archipelago come to educate themselves as teachers and mechanics, carpenters, etc. The young children attend classes taught by the older ones at the Normal School and are necessarily from Manila and vicinity. The majority of the children are mestizos, mixed Spanish, Chinese and Filipino, and represent the littoral population of the archipelago fairly well. A few individuals are probably of pure Spanish extraction. No attempt was made to segregate the mestizos or those of Chinese or Spanish extraction from the presumably pure Filipinos because any such attempt is necessarily imperfect and will be so until we understand better than we do at present the workings of Mendelian heredity in man.

Methods

The age of the children was obtained from each individual and verified as far as possible through the teachers. In Manila the school registers were also examined and the age verified in this way. Discrepancies occur in spite of all efforts to avoid them, but I believe nearly all the ages are exact, and the few that may not be are approximately correct. The year and month of birth were obtained in all except a few instances and the child reckoned to be a certain age if it was anywhere within six months of that age. For instance, if a child was born in January, 1902, and the records were made in July, 1908, the child was recorded as six years old, but if the records were made in July, 1907, the child was recorded as five years old, and if the records were made in August, 1908, the child was recorded as seven years old. This method is practically the same as obtaining from the child the nearest birthday, although in giving that the child is apt to miscalculate.

The youngest children whose teeth I examined were five years old, and at that age all of the temporary teeth have erupted; therefore the time of the eruption of the temporary teeth cannot be given.

The Eruption of the Permanent Teeth

This is determined by taking the average or mean number of teeth erupted or erupting at each age, as well as the "median," the "mode," and the "extremes."

The eruption of the permanent teeth begins about the age of 5 years, slightly earlier among the girls and slightly later among the boys of the German and American groups, but considerably earlier than this (Tables 1-6) among the Filipinos of both sexes. The Germans and Americans of both

The Beginning of Eruption and the End of Eruption of the Permanent Teeth

Table 1. *Filipino Girls*

	Upper		Lower	
Teeth	Begin	End	Begin	End
Median Incisors	before 5	5 to 9	before 5	5 to 9
Lateral Incisors	before 5	5 to 9	before 5	5 to 9
Canines	5 to 9	12 to 13	before 5	5 to 9
Median Premolars	10 to 11	12 to 13	5 to 9	12 to 13
Lateral Premolars	10 to 11	12 to 13	10 to 11	12 to 13
First Molars	before 5	5 to 9	before 5	5 to 9
Second Molars	10 to 11	14 to 15	5 to 9	12 to 13
Third Molars	12 to 13	?	14 to 15	?

Table 2. *Filipino Boys*

	Upper		Lower	
Teeth	Begin	End	Begin	End
Median Incisors	before 5	5 to 9	before 5	5 to 9
Lateral Incisors	before 5	11	before 5	10
Canines	before 5	11	before 5	11
Median Premolars	5 to 9	14	5 to 9	14
Lateral Premolars	5 to 9	15	5 to 9	15
First Molars	before 5	10	before 5	12
Second Molars	5 to 9	14	5 to 9	14
Third Molars	13	?	13	?

Table 3. *American Girls*

	Upper		Lower	
Teeth	Begin	End	Begin	End
Median Incisors	6	9	5	8
Lateral Incisors	7	12	6	9
Canines	9	15	8	13
Median Premolars	8	13	9	14
Lateral Premolars	8	14	9	15
First Molars	6	8	5	8
Second Molars	10	15	10	16
Third Molars	16	?	16	?

Table 4. *American Boys*

	Upper		Lower	
Teeth	Begin	End	Begin	End
Median Incisors	7	9	6	8
Lateral Incisors	7	11	7	10
Canines	10	14	9	13
Median Premolars	8	16	9	14
Lateral Premolars	9	16	8	16
First Molars	6	9	6	8
Second Molars	12	16	11	17
Third Molars	?	?	?	?

Table 5. *German Girls*

Teeth	Upper Begin	Upper End	Lower Begin	Lower End
Median Incisors	7	10	5	9
Lateral Incisors	7	11	7	10
Canines	8	15	8	12
Median Premolars	8	13	8	14
Lateral Premolars	8	14	9	15
First Molars	5	7	5	8
Second Molars	11	16	10	14
Third Molars	?	?	14 or 16?	?

Table 6. *German Boys*

Teeth	Upper Begin	Upper End	Lower Begin	Lower End
Median Incisors	6	11	6	11
Lateral Incisors	7	11	7	10
Canines	10	14	10	14
Median Premolars	8	14	10	14
Lateral Premolars	9	14	10	14
First Molars	6	9	6	7
Second Molars	11	16	10	16
Third Molars	?	?	?	?

sexes have almost exactly the same number of permanent teeth at the ages of 6, 7 and 8 years, after which the girls have a greater number of teeth than the boys until the age of 15 is reached, when the number of teeth in the two sexes is again about the same. The correlation of the eruption of the teeth and of the growth in stature of the sexes is close.

The girls of each group are more precocious in the eruption of the permanent teeth than the boys; they have a greater number of permanent teeth at each age, and the difference is greatest between the ages of 8 and 15 years, for at the age of 11 years the American girls have an average of 21.3 permanent teeth present, and the American boys have an average of only 17.3. The difference between the German boys and girls at this age is not so great, and they have only 16.7 and 19.5 teeth present for the boys and girls respectively. The difference between the Filipino boys and girls is still less, and they have a greater number of teeth present than either the German or Americans at the age of 11 years, 24.3 and 27.0 for the boys and girls respectively.

The Filipinos are much more precocious than either the Germans or Americans in the eruption of the permanent teeth, and there is little difference between the boys and girls in the number of teeth present at each age. The Americans are a little more precocious than the Germans in the eruption of the permanent teeth, and the difference between the boys and girls is greater among the Americans than among the Germans or Filipinos.

About the age of 15 years the children of both sexes in all the groups have nearly the same number of teeth, and after this age the German and American children maintain the same number of teeth up to the time at which the records cease (18 years), but the Filipino children continue to gain in the number of their teeth to the age of 20 and beyond, although the majority of the Filipinos have acquired the complete set of 32 teeth at the age of 20 years.

This is due to the early eruption of the third molars in the Filipinos, beginning at 13 years, and their later eruption in the Germans and Americans beginning at 16 years or later.

Sixty odd negro boys and girls, mostly mulattoes, were examined at Ann Arbor, and it is found that the negro boys and the American boys are almost parallel in the time of the eruption of their teeth, and the negro girls are only slightly more precocious than the American girls.

THE TIME AT WHICH APPROXIMATELY 50% OF EACH TYPE OF TOOTH IS ERUPTED

It is impossible to calculate exactly when 50% of the teeth are erupted, but approximate ages may be obtained for each type of tooth, which has been done and the results placed in Table 7.

Median Incisors. The lower median incisors erupt about the age of 6 years, and the upper at about the age of 7.5 years. This is the time of eruption in the American boys; it occurs earlier in the Filipino boys and later in the German boys, and the sexual differences are slight.

Lateral Incisors. The lower lateral incisors erupt about the age of 8 years and the upper lateral incisors erupt about the age of 8.5 years. They erupt only a little earlier in the German boys than in the German girls, but there is six months' difference in time between their eruption in the American girls and boys, the girls being earlier than the boys.

The upper lateral incisors erupt at about 8.5 years in the Filipino boys, and in the American and German girls, but at 9 years in the American boys and at 8 years in the German boys. The order of eruption of the lower lateral incisors is (1) Filipino boys, (2) American girls, (3) German girls, (4) German boys and (5) American boys.

Canines. The upper canines erupt at about 11.5 years of age, and the lower at about 10.5, except in the Filipinos where the eruption is at about 8 years for the uppers and 7 years

Table 7. *The physiological standard* (see page 610) *or the period of most rapid eruption of the permanent teeth, and the time at which* 50% *are present*

Teeth	Amer. girl	Ger. girl	Amer. boy	Ger. boy
Lower first molars	5– 6 yrs.	6– 7 yrs.	6– 7 yrs.	6– 7 yrs.
Upper first molars	5– 6 "	6– 7 "	6– 7 "	6– 7 "
Lower median incisors	5– 6 "	6– 7 "	6– 7 "	6– 7 "
Upper median incisors	7– 8 "	7– 8 "	7– 8 "	7– 8 "
Lower lateral incisors	7– 8 "	7– 8 "	7– 9 "	7– 9 "
Upper lateral incisors	8– 9 "	7– 9 "	8–10 "	8– 9 "
Upper median premolars	9–11 "	9–11 "	10–11 "	10–12 "
Lower canines	9–11 "	10–11 "	11–12 "	11–12 "
Lower median premolars	9–11 "	10–11 "	10–12 "	11–12 "
Upper lateral premolars.	10–11 "	10–11 "	10–12 "	10–12 "
Upper canines	10–11 "	10–12 "	11–12 "	11–12 "
Lower lateral premolars.	10–11 "	11–12 "	11–12 "	10–13 "
Lower second molars	10–12 "	11–12 "	11–14 "	11–14 "
Upper second molars	12–13 "	12–13 "	12–14 "	11–14 "

	Filipino boys	Filipino girls
Lower canines	5– 9	?
Upper canines	5– 9	?
Upper median premolars	5–10	?
Upper lateral premolars	7–11	?
Lower median premolars	10–11	?
Lower lateral premolars	10–11	?
Lower second molars	10–11	7–11
Upper second molars	10–11	7–13
Lower third molars	17–18	16.5–18.5*
Upper third molars	17–20	16.5–18.5*

* 50% of the Filipino girls do not have the third molars erupted until after 20 years.

for the lowers. The order of eruption of the upper canines is 1) Filipino boys, 2) Filipino girls, 3) American girls, 4) German girls, 5) American boys and 6) German boys. The notable exception to the general rule is that the Filipino boys are more precocious than the Filipino girls, although this may not be of great significance because so few Filipino girls were recorded. The order of eruption of the lower canines is 1) Filipino girls and boys, 2) American girls, 3) German girls, 4) American boys, 5) German boys. The girls' canines erupt six months earlier than the boys', and the American girls' canines erupt more than a year earlier than the American boys'.

Median Premolars. The upper median premolars erupt at about 10 years of age and the lower at about 11, except among the Filipinos where the eruption is a year earlier for the boys and two years earlier for the girls. The order of eruption is the same for the upper and lower median premolars, 1) Filipino girls, 2) Filipino boys, 3) American girls, 4) German girls, 5) American boys, 6) German boys, which is the usual order of eruption.

Lateral Premolars. The upper lateral premolars erupt at about 11 years of age, and the lower lateral at about 11.5, except among the Filipinos, where the boys' erupt, the upper at 9, the lower at 10.5; the girls', the upper at 10 and the lower at 10.

The order of eruption is, 1) Filipino boys and girls, 2) American girls, 3) German girls, 4) American boys, 5) German boys, the upper and the lower with the same order.

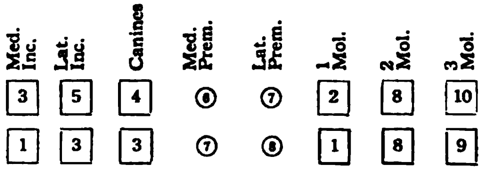
First Molars. The first molars erupt near the age of six years in all the groups except the Filipino boys where the age is six for the upper but five for the lower molars. There are so few Filipino girls on record that the eruption of the upper first molars among them at 7.5 years should not be considered. There is very little difference in time between the eruption of the upper and lower teeth. The American girls are slightly precocious and the German boys slightly backward in the eruption of the first molars.

Second Molars. The upper second molars erupt at about the age of 12.5 years and the lower at about 12, except among the Filipinos where the time of eruption is 10 for the girls and 10.5 for the boys, both upper and lower. The order of eruption is the usual one in the sexes and races.

Third Molars. The time of eruption of the third molars can be given only for the Filipinos, in whom it occurs about the age of 19 years.

From Table 7 we may construct the plan of the left side of a mouth in which the teeth are arranged as they would appear were we looking into the mouth, and inside of the symbol for each tooth put the number that represents the order of its eruption.

Plan of the order of eruption of the Filipinos' teeth (girls below ten not included):



Med. Inc.	Lat. Inc.	Canines	Med. Prem.	Lat. Prem.	1 Mol.	2 Mol.	3 Mol.
3	5	4	⑥	⑦	2	8	10
1	3	3	⑦	⑧	1	8	9

Plan of the order of eruption of the Germans' and Americans' teeth:

Both sexes	Med. Inc.	Lat. Inc.	Canines	Med. Prem.	Lat. Prem.	1 Mol.	2 Mol.	3 Mol.
	4	6	11	⑦	⑩	3	14	16
	2	5	8	⑨	⑫	1	13	15

Resumé. The usual sex-race order of the eruption of the teeth is, 1) Filipino girls, 2) Filipino boys, 3) American girls, 4) German girls, 5) American boys, 6) German boys, as determined by the time at which approximately 50% of the teeth have erupted.

By the same standard the order of the eruption of the types of teeth for the Germans and Americans is, 1) first molars, 2) median incisors, 3) lateral incisors, 4) median premolars, 5) canines, 6) lateral premolars, 7) second molars, 8) third molars.

All the lower teeth erupt before the upper except the premolars.

The time of the eruption of the canines is of interest, especially among the Filipinos, in which the canines erupt before the eruption of the upper lateral incisors. The order of eruption of the canines in relation to that of the premolars among the Germans and Americans is, 1) upper median premolar, 2) lower canine, 3) lower median premolar, 4) upper lateral premolar, 5) upper canine, 6) lower lateral premolar.

The work of Chérot(5) is of value because it is of recent date, and because he procured data from 20 to 30 children of each sex at each age. The time of the ***beginning of eruption*** and of the ***end of eruption*** as he found them in the French may be compared with my records of the Ann Arbor children:

Table 8. *Percentage of each tooth erupted at a given age*

	Chérot—French		Bean—Ann Arbor	
Upper first molars......	12.19% at 5 yrs.	100% at 8	6.25% at 5	94.5% at 8
Lower first molars......	19.51 "	100 "	18.75 "	97.5 "
Upper median incisors..	0.0 "	100 at 9	0.0 "	91.6 at 9
Lower median incisors..	2.43 "	100 "	6.25 "	98.5 "
Upper lateral incisors ..	0.0 at 6 yrs.	100 at 10	0.0 at 6	83.5 at 10
Lower lateral incisors ..	2.27 "	100 "	1.5 "	96.5 "
Upper median premolars	2.5 at 7 yrs.	100 at 13	0.0 at 7	92.5 at 13
Lower median premolars	2.5 "	100 "	0.0 "	96.0 "
Upper lateral premolars.	2.38 at 8 yrs.	97.05 "	0.75 at 8	85.25 "
Lower lateral premolars.	4.76 "	100 "	0.325 "	83.5 "
Upper canines.........	0.0 "	97.05 "	1.0 "	80.4 "
Lower canines.........	4.76 "	100 "	2.88 "	97.1 "
Upper second molars...	8.51 at 10 yrs.	100 at 14	0.25 at 10	78.9 at 14
Lower second molars...	12.76 "	100 "	4.12 "	91.1 "
Upper third molars.....	19.5 years		1.75 at 16	
Lower third molars.....	19.5 years		3.5 "	

It is to be seen from Table 8 that the French children are earlier than the children of Ann Arbor both in the *beginning of eruption* and in the *end of eruption* of the teeth, except in the *beginning of eruption* of the lower median incisors and upper canines; wherefore it is evident that the French at any age are more mature in the eruption of the teeth than the children of Ann Arbor.

Chérot believes there are four periods of acceleration in the eruption of the permanent teeth—from six to eight and a half years, when some teeth are erupting all the time; from 10 to 11 years; at 12 years; and about 20.5 years, during the eruption of the third molars. The periods of 10 to 11 and at 12 should be combined because they run together, thus leaving three periods, which have been associated by others with the eruption of the three series of molar teeth. Welcker (16) gives the time of eruption of the permanent teeth for the Germans as follows:

First molars, 7 years.
Median incisors, 8 years.
Lateral incisors, 9 years.
Median premolars, 10 years.
Canines, 11 to 13 years.
Lateral premolars, 11 to 15 years.
Second molars, 13 to 16 years.
Third molars, 18 to 30 years.

The German are more backward than the French, which reminds us that the Germans of Ann Arbor are more backward than the Americans of the same place in the eruption of the permanent teeth.

Hrdlicka (10) has published the only detailed data of the examination of children's teeth that I have been able to find in the literature. He examined the teeth of the Apache and Pima Indians of North America, and from his records he concludes that the teeth of the Indians appear at about the same ages as the teeth of the whites, with the exception of the canines and second molars, which apparently erupt earlier in the Indians than in the whites. I have calculated the *beginning of eruption* and the *end of eruption* of the teeth in the Indians, which is based on the stature rather than the age, because the age of the Indians was not obtained by Hrdlicka. The age is calculated from the stature by Hrdlicka, and he remarks that it is doubtless imperfect.

The order of eruption is similar to that of the Europeans or white peoples, and different from that of the Filipinos, because in the latter the canines erupt before the premolars, whereas in the others the canines erupt at the time of the

Table 9. *The eruption of the teeth in the Indian*

	Male		Female	
Teeth	Begin	End	Begin	End
First molars.................	5.2	7	5.6	6
Median incisors..............	6.2	7	5.6	8.5
Lateral incisors..............	7	10	7.2	9.5
Median premolars............	7.8	13	7.2	13
Lateral premolars............	8.6	14.4	7.4	13
Canines......................	9	13	7.8	13
Second molars...............	9.5	13	9.3	13.8
Third molars................	16.5	...	14	...

eruption of the premolars, or as noted above; the lower canines erupt between the eruption of the upper and lower median premolars and the upper canines erupt between the eruption of the upper and lower lateral premolars.

The eruption of the teeth begins later in the Indians than in the whites, and ends earlier. The teeth of the Indians erupt more promptly than those of the whites, and the canines, second and third molars erupt earlier in the Indians than in the whites.

Boas (4), and Boas and Wissler (3) have made reports as to the eruption of the permanent teeth in American whites but their work has been inaccessible to me and what I give is based on abstracts. Boas published the following results in *Science* recently with the remark that they "are not very accurate."

	Age in years			
	Boys		Girls	
Teeth	Boas	Bean	Boas	Bean
Inner permanent incisors..........	7.5	7.0	7.0	6.65
Outer permanent incisors.........	9.5	8.4	8.9	8.00
Bicuspids.......................	9.8	11.1	9.0	10.6
Canines........................	11.2	11.6	11.3	10.5
Second molars..................	13.2	12.6	12.8	12.0

I do not know how the calculations were made by Boas but when compared with my results of the time when approximately 50% of the teeth are erupted, his records show a retarded eruption of all the teeth except the premolars, which are precocious, and erupt more than a year earlier than the premolars of the Germans and Americans of Ann Arbor. The canines in his records erupt about two years later than the "bicuspids" (premolars?), which is very unusual. Boas and Wissler also place the end of eruption of the permanent teeth as follows: First molars, 9 years; median incisors, 12 years; bicuspids, 6-12 years; canines, 6-15 years; lateral incisors, 15 years; and second molars, 7-15 years.

Morphologic Form and Teeth

In a former study of Filipino students (1 and 2) I called attention to the bad teeth of what I then called the Iberian type, but have since named the Hyper-onto-morph. This form is usually small, slender, narrow nosed, and has a long slender face with pointed chin, and a long narrow head with projecting occipital region, although at times the form may be fat, the face may be short and not slender, the nose may be stubby, and the head may be rounded; but at all times the form has characteristic ears, with everted anthelix, tragus and antitragus, and rolled back helix. The form is identical with the Mediterranean race of Sergi. In studies subsequent to those on the Filipino students, I made studies in Manila, in Taytay, a town near Manila, and in New Orleans, I have demonstrated that this form is what I call an epitheliopath, a form which is very susceptible to diseases of the structures derived from epithelium such as the lungs, alimentary canal and central nervous system. The Hyper-ontomorph is quite distinct from the round headed, round faced form with more or less infantile nose and bowl shaped ears which I call the Hypo-onto-morph. However, no observations were made of the ear form of the school children represented in this study, hence only the cephalic and facial indices, and the relative size of the occipital and parietal regions of the head can be utilized here. This will not effect a complete segregation of the Hyper-onto-morph and the Hypo-onto-morph, but it will indicate that a complete segregation such as might be accomplished by the use of the ear form and other factors would give a marked contrast between the two forms in the eruption of the teeth, in the number of good sets present, and in the average number of bad teeth. As it is, the segregation by cephalic and facial indices gives considerable difference in all three of these conditions.

The two forms are segregated by putting those with a cephalic index below 80 and a facial index below 120 in one group, and those with a cephalic index of 80 and over and a facial index of 120 and over in another, and the remainder or those with cephalic index of 80 and over and a facial index of less than 120, or with cephalic index of less than 80 and a facial index of 120 and over, in a third group. The three will be called the Hyper-onto-morph, Hypo-onto-morph and Remainder. Below the age of 11 years the dividing figure of the cephalic index is 81 instead of 80.

Permanent teeth erupted. The Filipinos from 5-10 years of age may be neglected because of the few individuals who come under observation. The average number of teeth erupted among the German and American boys from 5-10 years of age is

Hyper- 9.87 Hypo- 9.14 Remainder 9.45

The Hyper- is more precocious than the Hypo- from 5-10 years of age.

The average number of teeth erupted in all the groups from 11 to 16 years of age, including both sexes is

Hyper- 26.6 Hypo- 24.1 Remainder 25.4

The Hyper- is more precocious than the Hypo- from 10-16 years of age. It is therefore evident that the Hyper, at all ages, is more precocious in the eruption of the permanent teeth than the Hypo, and this difference amounts to one or more teeth.

Number of good sets of permanent teeth present. The Filipinos below the age of 10 years may be neglected as usual. The percentage of good sets of teeth among the Germans and American boys and girls from 5 to 10 years of age is

Hyper- 80.33 Hypo- 80.98 Remainder 82.8

The percentage of good sets of teeth among the boys and girls of all the groups from 11 to 16 years is

Hyper- 18.3 Hypo- 46.8 Remainder 34.4

Among the Filipinos alone from the age of 17-30, both sexes, it is

Hyper- 9.3 Hypo- 34.3 Remainder 24.2

It is evident that the Hyper- has fewer good sets of teeth at all ages than the Hypo.

Average number of bad permanent teeth per individual. The Filipinos below the age of 10 years may be disregarded. The average number of bad teeth below the age of 10 years among the German and American boys and girls is

Hyper- 0.468 Hypo- 0.36 Remainder 0.30

The average number of decayed teeth in all the groups from 11 to 16 years of age is

Hyper- 3.35 Hypo- 1.79 Remainder 2.09

The average number of decayed teeth among the Filipinos alone from 17 to 30 years of age is

Hyper- 3.33 Hypo- 2.53 Remainder 3.08

It is evident from a consideration of the average number of bad permanent teeth that the Hypers have the worst teeth and the Hypos have the best.

The number of individuals in each group. Racial differences may be found by calculating the relative number of Hyper and Hypo individuals in each group. Between the ages of 5 and 16 the Filipinos have 1 Hyper to 15.2 Hypos, the Germans have 1 Hyper to 5.3 Hypos, and the Americans have 1 Hyper to 1 Hypo. From 17 to 30 years the Filipinos have 1 Hyper to 3.8 Hypos.

Sexual differences may be determined in the same manner. The Filipino girls have 1 Hyper to 28 Hypos, and the Filipino boys have 1 Hyper to 4.6 Hypos; the German girls have 1 Hyper to 7.1 Hypos, and the German boys have 1 Hyper to 4.3 Hypos; and the American girls have 1 Hyper to 1.2 Hypos, and the American boys have 1 Hyper to 0.84 Hypos.

It is also noticed that the relative number of Hypers increases with age. This is especially noticeable with the American boys for whom the ratio is 1 Hyper to 3 Hypos at 8 years of age and 12 Hypers to 1 Hypo at 16 years of age.

Hyper-morphism is a condition of development in a certain direction, a condition of greater age, a male condition, and a condition characteristic of the American (white). Hypo-morphism is a condition of development in another direction, a condition of less age, a female condition, and a condition characteristic of the Filipino.

A number of other conditions besides the shape of the head and face characterize the Hyper and the Hypo forms, such as the shape of the nose, the size of the regions of the head, the ear form, etc., the relative lengths of the extremities and of their parts, but it will suffice to give only one of these here, that is, the relative size of the occipital and parietal regions of the head.

The circumference of the forehead, frontal, parietal and occipital regions of the head of the school children were taken but they will be reserved for future studies of head form that are at present under way; only the relative size of the occipital and parietal regions of the head to each other will be given here.

The points selected from which to measure the circumference of the regions of the head are the dorsal extremities of the middle roots of the zygoma on each side of the head immediately ventral to the external ear, a place that is easily accessible and distinctly felt. The tape was passed from the point on the right side to the point on the left side around the maximum protuberance of the parietal and occipital regions of the head, and this distance recorded as the circumference of the part. An index is obtained that is called the occipito-parietal index, by multiplying the occipital circumference by

100 and dividing by the parietal circumference. This gives the occipital circumference in terms of the parietal, the latter always being 100. A high index denotes a large occipital region, a low index the reverse.

The occipito-parietal index. The occipito-parietal index in the German and American children from 5 to 10 years of age is

Hyper 80.9 Hypo 79.9

and from 11 to 16 years of age is

Hyper 82.2 Hypo 79.4

The occipito-parietal index in the Filipino boys is

5 to 10 years......	Hyper 88.4 (1)	Hypo 78.3
11 to 16 years......	Hyper 81.9	Hypo 76.7
18 to 30 years......	Hyper 83.4	Hypo 79.9

The index of the Filipinos is less than that of the Germans and Americans at the same age, and the index of the Hypo in the Filipino from 17 to 30 years of age has reached that of the German and Americans at the age of 5 to 10 years, but the index of the Hyper among the Filipinos at 17 to 30 years of age has passed that of the Germans and Americans at the age of 11 to 16. The index increases with age except that the Hypos among the Germans and Americans do not change.

The Hypo has a relatively smaller occipital region in the Filipino than in the German, and a relatively larger occipital region in the American than in the German. The same is not true for the Hyper, for in them the occipital region is about the same for the American and Filipino, but relatively smaller for the German.

The sexual differences indicate that the male has a relatively larger occipital region than the female, and the female a relatively larger parietal region than the male although the difference is not great.

Magitot (13) called attention to the differences in the decay of the teeth in Normandy and Brittany, and attributed the difference to the type of people in the two compartments of France. In Brittany are the Celts or Gauls, who are small, with dark hair and eyes, and broad head, and with good teeth; in Normandy are the Belgians or Kymries, who are tall, with fair hair and eyes, and long head and with bad teeth. The color of hair and eyes seems to be incidental, because in those I examined with bad teeth and of the Hyper-onto-morph form, the color of hair and eyes was of all shades. In Southern Europe the long head has dark hair and eyes and in Northern Europe fair hair and eyes, and in Central Europe the broad head has dark hair and eyes, and in Eastern Europe the same form has fair hair and eyes. The morphologic form is independent of pigmentation and I believe the time of eruption of the permanent teeth and the extent of their decay are due to inherent differences in the morphologic form of the individual.

THE PHYSIOLOGICAL STANDARD

The foregoing pages have been written to demonstrate that the time of the eruption of the teeth, or of any tooth, varies with sex, with race, and with morphologic form, as well as with age, and it is necessary to bear in mind all the facts in using the eruption of the teeth as a physiological standard for testing development.

I offer a protest against the use of the term physiological age, and suggest in its place the term physiological standard, because any age may be a physiological age, and all ages are physiological unless they are pathological. What is usually meant by the physiological age is, I suppose, the relative development of the individual as measured by some standard other than age. It is therefore illogical to use the term age when age is not meant.

No single factor, such as stature, or weight, or the epiphyses of the bones, or the eruption of the teeth, or the presence or absence of secondary sexual characters, or any other factor will be sufficient alone to establish the relative development of the individual, although one factor may be worth more than another in this respect, and I shall attempt to show the value of the time of eruption of the permanent teeth as a physiological standard in the determination of the relative development.

The various structural parts, or organs, of the body do not develop synchronously, but by comparing the periods of acceleration and retardation in the growth of the skeleton with the periods of acceleration and retardation in the development of the permanent teeth, taken as a whole, and by further considering individual teeth, and also the work on general development by Donaldson, Jackson, Hatai and others (6, 9, 11, 12 and 15), I have arrived at a law which may be expressed as follows:

There are one or more periods of acceleration alternating with periods of retardation in the development of any one of the structures of the body. The periods of acceleration in the development of one structure may be synchronous with the periods of retardation in the development of another structure.

Thus the period of the first six months after birth is one of rapid growth in body length, and this is followed by a period of comparative rest of the body while the eruption of the temporary teeth is taking place, all of which are through the gums by the third year. This activity in dental growth is followed by a period of rest. Following this there is a second period of rapid growth in length (stature), subsequent to which the permanent teeth begin to erupt, after which the growth of the body is again accelerated, to be followed by a second rapid eruption of the permanent teeth, and then another rapid growth of the body which is succeeded by puberty.

The lower extremities develop most rapidly from birth to 6.5 years, according to Godin (8 and 15), and they develop more rapidly than the trunk from 6.5 to 15.5 years, after which, from 15.5 to 17.5 years, the trunk develops more rapidly than the lower extremities. The great factor in the increase of stature from birth to 15.5 years is the growth in length of the lower extremities; therefore the periods of acceleration and retardation of growth refer primarily to the long bones. The development of the teeth and of the long bones are therefore reciprocal; the periods of acceleration in the development of one correspond to periods of retardation in the development of the other. In the consideration of the eruption of the permanent teeth it is necessary to bear in mind the periods of acceleration and retardation in their development, the earlier the beginning of the periods of acceleration the more precocious the child. The periods of acceleration in the development of the permanent teeth begin necessarily before the periods of most rapid eruption; the eruption of the teeth is merely the consequence of their previous rapid development.

Each tooth may be considered from the standpoint of the time at which it first appears in any individual of a group, and the time at which it last appears in any individual, as well as from the time at which 50% of the individuals have the tooth erupted, and the time during which the greatest number of individuals have the tooth erupting. Suppose we take the left upper second molar tooth in the American girls (Table 3). This tooth has not erupted in any American girl at 9 years of age, but 2% appear at 10 years, and the latest age at which any erupt is 15 years; all are erupted at 16 years. Approximately 50% have the tooth erupted at 12 years; therefore there is a shorter period for the eruption of the first 50% (10-12 years) than for the eruption of the second 50% (12-15 years). The greatest number of teeth erupt between 11 and 12 years (41%), although there is a second period of rapid eruption between 13 and 14 years. This may be a segregation of the precocious and backward American girls.

In like manner we may obtain the same data for all the other teeth of the American girls, and of the teeth of all the other boys and girls. The upper teeth of the same type on the two sides, as the upper median incisors or the upper second molars, erupt at so nearly the same time that they may be put together. The period of most rapid eruption almost invariably coincides with the time at which 50% of the teeth have erupted; therefore the limits of the first-mentioned period will cover the second. A table may be constructed showing the results, and this table will be the physiological standard for each group of individuals in relation to the eruption of each tooth (see Table 7). The ages given are the ages at which the teeth normally appear. If the teeth appear earlier in any individual, that individual is precocious; and if later, backward. See Tables 1-6, from which the data for Table 15 are taken.

The physiological standard may be utilized to greater advantage with increasing age, because the racial and sexual differences increase with age. A word as to one way in which the table may be of use. Take a German girl of 10 years, when all the incisor teeth, the first molars, premolars and canines may be erupted; and a German boy, who may not have all these teeth erupted until 11 years of age; yet at 11 years he may be at the same physiological standard as the girl at 10 years. Should either one have all the teeth mentioned before the age specified, there would be evident precocity. In like manner evident backwardness may be determined.

The teeth are more convenient and more exact as a means of determining the physiological standard than stature, or weight, or the growth of the bones, or secondary sexual characters, etc., and they may be of greater value than any other means that can be utilized. The teeth can be seen, counted and identified by almost anyone after a little experience, and they are either present or absent, therefore very definite.

Precocity in the eruption of the permanent teeth is a sign of Hyper-morphism, and Hyper-ontomorphs are epitheliopaths, who are especially susceptible to diseases of the alimentary canal, the lungs and the central nervous system; therefore precocious children should be shielded from injuries to the susceptible organs.

Backwardness in the eruption of the permanent teeth is a sign of Hypo-morphism, and Hypo-ontomorphs, too, are probably susceptible to diseases of organs other than those mentioned, and they should be shielded from injuries to the susceptible organs.

THE SCHOOL GRADE FOR EACH YEAR OF AGE. MODE

The modal grade, or the grade that has the greatest number of individuals at each age, varies little with sex, but the Germans are about one year behind the Americans. This corresponds with the backwardness of the Germans in the eruption of the permanent teeth, and indicates considerable correlation of mental and dental development. This is true not only of the modal grade, but also of the grades above and below the mode. At each age from 7 to 14, inclusive, the children who are below the modal grade have an average of 0.9 of a tooth less than those in the modal grade, and the children who are above the modal grade have an average of 0.8 of a tooth more than those in the modal grade. The difference is greatest at 10 and 11 years, when the second period of the second dentition is at its height, and the difference at these two ages amounts to 1.5 and 1.8 teeth for those below and above the mode respectively.

It will be recalled that there is a period of one year during which the greater number of teeth of any form erupt, and during this year in nearly every case 50% of that form of tooth has erupted. From this a physiological standard, or age of eruption of each tooth, was determined. Evidence is therefore produced to indicate that the eruption of the teeth is a better criterion than age as a standard of both physical and mental development.

This evidence is not conclusive for each individual but only as an average or modal factor, because some individuals with fewer teeth than normal are above the modal grade, and some individuals with more teeth than normal are below the modal grade. Other factors therefore play a part and must not be overlooked. For instance, one child who was advanced in school grade beyond her age, and who had less than the normal number of teeth present, was the child of a teacher, and had evidently been pushed in school work.

However, the condition of the teeth, both as to eruption and decay, may be utilized and may be of value in determining the relative development of the individual.

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ON THE STRUCTURE OF THE ERYTHROCYTE

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FOUR FIGURES

This paper was undertaken with the hope of contributing something as to the structure of the so-called stroma of erythrocytes and as to the presence and character of a capsule or cell-membrane belonging to them.

The fact that the mammalian red blood corpuscle upon losing its nucleus becomes biconcave, its peripheral ring remaining thicker than its central region from which the nucleus has been lost, has always suggested the existence of a supporting framework. Were the corpuscle merely a hemoglobin-carrying sac borne in the blood stream, the natural tendency would be for it to assume a spherical form, the pressure on all sides being equal. The mammalian erythrocyte after being carried through capillaries smaller than its diameter, and after being drawn around angular curves of capillaries, which may stretch and modify its form considerably, always resumes its original form when returned to larger capillaries. This not only suggests a supporting frame-work for its content but also that this framework is plastic or even possesses certain elasticity.

The question of a membrane about the corpuscle is most disputed in the discussions. The most frequently advanced theory against the existence of such is that the corpuscle possesses no membrane at all but is merely covered by a film of lecithin or other lipoid substance acquired from its environment, and Norris (Physiology and pathology of blood '82) even suggests evidence that fluid droplets enclosed by lipoids (myelin) tend to assume flattened shapes, while when enclosed by films of ordinary fats they are invariably spherical. The very probable presence of a film of some lipoid or fat surrounding the entire corpuscle is seldom disputed and is accepted here. This is indicated by and explains the phenomena of forming into rouleaux and is supported by other arguments as well. But the presence of such a film need not disprove the existence of a membrane or capsule as a structure belonging to the corpuscle itself and which may be covered without by a film of lipoid substance. Fluid droplets enclosed in lipoid or fat films when shaken will become divided into smaller droplets and droplets of greatly varying size, whereas the erythrocytes of normal blood are strikingly uniform in size and while shaking them may break up or burst many of them, fragments resulting do not assume the form of the original corpuscle. Further, it seems very improbable that a film of lipoids alone would result in the folded and crumpled appearances shown by the so-called 'crenated corpuscles' resulting from extraction of a portion of the content. On the contrary, it would seem that such a film, still in the blood plasma, would merely thicken instead of becoming folded. Also, crenated corpuscles have lost the biconcave form, do not have the flattened shape suggested by Norris for fluid droplets surrounded by a film of lecithin. Crenation is suggested here as indicating the presence of a membrane intrinsic to the corpuscle which has become folded due to partial extraction of the original content by exosmosis, the crenated corpuscle becoming approximately spherical, due to a disturbance or destruction of its original internal structure by the process. The chemical compound, hemoglobin, so far as is known, has no anatomical structure. It is a complex organic compound in solution capable of various degrees of dilution. The loss of the biconcave form in crenation and the assumption of the spherical form in swelling from the action of distilled water, for example, suggest the destruction of a framework in which the hemoglobin was supported and by which the biconcave form of the nonnucleated corpuscle was maintained.

The original cell, the typical cell, possesses a framework of spongioplasmic filaments, a cytoplasmic and karyoplasmic reticulum, in the meshes of which are the more fluid portions (hyaloplasm) and the various forms of granules comprising the structure and content of the cell. In the functional differentiation of certain cells a marked increase in the evidence of a cytoplasmic reticulum is well known. The neuro-fibrillae of the nerve cell, for example, consist of anastomosing filaments more abundant and more evident than in the germinal or neuroblast stage of this element. Certain functioning gland cells show a reticulum in their cytoplasm. Hardesty ('05) and Nemiloff ('10) have shown that the emulsion comprising the medullary sheath of the nerve fiber has its component globules suspended and supported by a delicate reticulum, Hardesty showing this reticulum to be continuous into the membrane or neurilemma without and into a thinner bounding membrane (axolemma) about the axone of the nerve fiber, and that this framework and these two membranes, and not the fat of the sheath, maintain the shape of the sheath. He considered the membranes of the sheath as condensations of the internal framework. It is very probable that the corpuscle of adipose tissue, the fat cell, possesses an internal framework continuous with its capsule, both maintaining its general shape. Schäfer (vol. 2, part 1, Quain's Anatomy, 11th edition, '12) cites the fact that an erythrocyte, that of the newt for example, may be cut into two without resulting exudation of its content. Like the medullary sheath, the muscle fiber, the nerve cell or the fat corpuscle, the erythrocyte is an example of an especially differentiated arrangement for the performance of a special function.

The findings in the literature dealing with the structure of the red blood corpuscles seem to vary according to the methods of preparation used by the various authors and according to the different interpretations of the results obtained by them. Of the very voluminous literature, many of the papers consulted indicate a lack of familiarity with histology in general and an incompleteness of investigation to an extent that they seem of no value here. However, some authors give definite statements as to what they deem the structure of the erythrocyte and a number have considered the subject thoroughly.

Renant in his Histology ('89–'93) says red blood corpuscles possess no true cell-membrane, but merely a peripheral condensation of the cytoplasm such as that formed about a cell when exposed to air. Von Ebner (in Kölliker's Handbook, '02) states that a membrane must be assumed on the surface of the erythrocyte, a membrane insoluble in water and which allows osmosis, but which cannot be called a membrane in the ordinary sense and may be similar to the exoplasm of other cells. Löhner ('07) believes that a true histological membrane, similar to a cell membrane, is improbable. His method of preparation of the corpuscles for study consisted in crushing mammalian corpuscles on the slide. He also tried drying them in indifferent substances. He describes them as jelly-like and elastic in character with a thinner, more compact peripheral layer and a broader less compact inner region, similar to the exoplasm and endoplasm of Protozoa. If the outer compact layer is referred to as exoplasm, he thinks the superficial part of this may be termed a physical membrane or plasma-film. Dehler ('95) studied the red corpuscles of the chick, fixing them in sublimate solution and staining with iron-hematoxylin. He described the convex cells as possessing a sharp border or rind of .25 to .5 μ in thickness. Heidenhain ('96), working with the red blood corpuscles of Proteus, using the same method as Dehler, found the same appearances. Nicholas ('96), likewise using the same procedure, found the sharp border manifest on the erythrocytes of the chick, salamander, triton and viper.

Meves ('04 and '06) studied amphibian red blood corpuscles (frog and salamander). After condemning the technique used by Weidenreich and showing the results obtained by the latter were artifacts, he describes a very complicated procedure used by himself. In general this consisted of dried smears on the slide subjected to warmth for 30 minutes, then subjected to Flemming's fluid (weak formula) plus 1 per cent sodium chloride, washed in running water, stained with safranin, hematoxylin and safranin and Gentian orange, decolorized with neutral alcohol, and cleared and differentiated in clove oil. He describes the corpuscles as showing circumferential fibrils, which were disposed either in an arrangement parallel to the surface or in the form of a continuous skein, and radial fibrils running, some from the periphery toward the center of the corpuscle and some crossing each other, forming a net. In some cases the net-work arose only in part from the peripheral arrangement. He refers to the circumferential fibrils as a membrane which is continuous with the fibrils of the network within, and he interprets the fibrils as resulting from linear arrangements of mitochondria, granules having fused to form them. He thinks the arrangement of the fibrils is similar to that described by Heidenhain for Krause's membrane in muscle fibers, the fibrils continuing into the membrane (sarco-lemma) in a regular system. Shäfer ('05) suggests that Meves' circumferential or peripheral fibrils merely represent a part of the reticulum of the corpuscle.

Růžička ('03 and '06) worked with frog, guinea-pig and human blood. He stained with a dilute solution of methylen blue both without and after the action of 1 per cent pyrogallic acid, which latter he thought dissolved hemoglobin. The drop of blood was mounted in normal salt solution and the methylen blue solution (0.5 gram to 1000 cc. of water) added at the edge of the cover-glass. When used, the pyrogallic acid was applied followed by the methylen blue solution. Blood from the three sources gave the same results. All showed a fine meshed reticulum with occasional knobs at the junction of its filaments. He did not think an actual membrane is present but that the corpuscle is bounded by the reticulum. The knobs at the junction of the fibrils of the reticulum being found smaller and fewer after the action of pyrogallic acid, he assumed them to represent hemoglobin. He denied the possibility that the reticulum represented a coagulation product, thinking the meshes too fine and uniform and not arranged as coagulum filaments.

In the mammalian erythrocytes, Růžička also observed the previously described large granules dispersed in the center of the corpuscle, the so-called "nucleus of the mammalian corpuscle." Quoting Löwit ('87) as claiming a character for these granules in the rabbit similar to nuclear chromatin, he claims they are only present in case of incompletely dissolved hemoglobin and are thus analagous to the larger of the knobs described at the junctions of the filaments of the reticulum and therefore are not of chromatin nature.

Bryce ('04) studied the erythrocytes of the larvae of Lepidosiren paradoxa. He fixed the tissues with the blood vessels containing the erythrocytes *in situ* and used sections of 10 μ. He used sublimate-acetic as a fixing fluid. This was tried in this laboratory but was found unsuited for the study of adult erythrocytes in that it precipitates hemoglobin. Bryce's illustrations show that at least in the erythrocytes of these larvae, not having acquired sufficient hemoglobin to color them, there is a reticular structure in the cytoplasm connecting with a membrane at the periphery, and he describes a meshwork or reticulum in them which was radially arranged from the nucleus to the periphery, the meshes of which in section were 3 to 4 μ in size. At the nodal points or junctions of the filaments forming the meshes he found "strongly refractile granules of considerable size" and he states that in some of the corpuscles the filaments near the nucleus appear as arranged in parallel threads, extending from the nucleus a short distance toward the periphery. He does not pass judgment on the nature of the membrane observed, but states that he was dealing with very young corpuscles.

MATERIAL AND METHODS

As is known, the Amphiumae carry the largest red blood corpuscles of any vertebrate as yet examined. One of the species of this animal, the Amphiuma means (the 'blind eel') being easily obtainable in the ditches of New Orleans, a study of the structure of its corpuscle was suggested by Professor Hardesty. Measurements of its corpuscles in the fresh gave, measured on the flat, an average of 72.9 μ in length by 44.5 μ in width. With the same technique as finally employed for those of the Amphiuma, erythrocytes from the alligator, frog, snake, guinea-pig and human were also prepared and studied in comparison.

Obviously, a study of the internal structure of the erythrocytes of Amphiuma and those of other animals, or the study of membranes probably existing, could not be accomplished in any detail except with very thin stained sections. If a structural framework existed and if a membrane possessed visible structure, to observe such, it was equally obvious that the hemoglobin carried must be wholly, or at least partially removed from the specimens. Therefore any accomplishment of the purpose in mind depended largely upon the technique employed.

The greatest difficulty was encountered in finding a fixing fluid suitable for the purpose. A fluid was desired in which hemoglobin is dissolved rather than precipitated. Hemoglobin not removed or precipitated within the corpuscle of course obscures whatever other cytoplasmic structure it may possess. Further, a fixing fluid was necessary whose osmotic action results in neither appreciable shrinkage nor swelling of the corpuscles, and one the diffusion currents resulting from whose action does not break up the structural content.

Osmic acid, bichloride of mercury, chromic acid and its potassium salts precipitate hemoglobin, and fluids in which any of these act of themselves were found impossible for the results desired. It is doubtful whether, according to Růžička ('03), pyrogallic acid is a solvent of hemoglobin. It was deemed necessary here to fix, embed and section the corpuscles, which he did not do, and no suitable fixing fluid containing pyrogallic acid has been devised. Hemoglobin is dissolved in alcohol, distilled water, acetic acid and formic acid, and formalin does not precipitate it. The action of alcohol alone distorts the corpuscle and produces shrinkage and rupture, and acetic acid, formic acid and formalin not only produce swelling but in themselves are very poor fixing agents for the structure of cells. Van Gehuchten's (Carnoy's) fluid, containing absolute alcohol, acetic acid and chloroform, was tried and found to rend the fresh corpuscles into small fragments.

Bryce obtained his results after the action of sublimate-acetic, but he was dealing with corpuscles of larvae which probably contained considerably less hemoglobin than the corpuscles of the adults whose study was here desired. After trying a number of fluids containing corrosive sublimate and acetic acid, it was decided that the action of the sublimate in all precipitated the hemoglobin. Suggestive but incomplete results were obtained with corpuscles fixed in a mixture containing 5 cc. saturated aqueous solution of bichloride of mercury, 2 cc. glacial acetic acid, 5 cc. 40 per cent formaldehyde, and 88 cc. 95 per cent alcohol. Preparations of nucleated corpuscles after this fluid showed a cytoplasm more or less transparent in places and a distinct membrane bounding the periphery. In the clearer places in the cytoplasm a fairly well marked reticulum could be discerned. In preparations of mammalian (non-nucleated) corpuscles such were much less indicated.

Of all the fixing fluids tried, the most satisfactory results were obtained after using a well ripened mixture containing the following parts:

Aqueous 3 per cent potassium bichromate	100 cc.
Commercial (40 per cent) formaldehyde	4 cc.
Glacial acetic acid	5 cc.

When first made, this fluid has the color of the bichromate solution, but if allowed to stand or if warmed it becomes a dark greenish brown, due chiefly to the oxidation of the bichromate in the resultant reactions. Our best results were, or maybe happened to be, obtained with a mixture which had been standing several weeks. The formation of formic acid is one of the results of the ripening process.

In using this fluid (and all those tried) a fairly large shell-vial was filled about half full of the fluid and, gently shaking it, the blood was dripped, drop by drop, directly from the animal into the fluid. Even by agitating the mixture while adding the blood, some coagulated clumps cannot be avoided. The corpuscles in these clumps were found not so good for study as those floating free in the fixing fluid. All finally settle upon the bottom of the vial and the fluid may be removed with a pipette or decanted. The fluid was allowed to act for twelve hours. Changing it once or twice was thought to result in better extraction of the hemoglobin.

This fluid does not require a preliminary washing of the material in water. Small paper boxes were made from ordinary thin letter paper, labels written on the sides in pencil, and the accumulated corpuscles transferred to the boxes by pipette. The boxes nearly full of fixing fluid and corpuscles were then placed in a stender dish containing 30 per cent alcohol to a depth of about half the depth of the boxes. In 5 to 10 minutes the corpuscles settle to the bottom of the box and some of the fixing fluid may be pipetted away. Gradual dehydration is accomplished by the transfusion of the alcohol through the paper walls of the boxes. If several boxes are carried in a small stender dish, the 30 per cent alcohol should be changed during the hour. Then the 30 per cent alcohol in the stender dish was replaced with 40 per cent alcohol and so on with grades of alcohol progressively increasing by 10 per cent in strength up to 90 per cent, which was replaced with 95 per cent alcohol and this in turn by absolute. To insure complete transfusion of the different grades and the action of each upon the corpuscles, the paper boxes should remain in each alcohol at least one hour with the stender dish covered.

From the absolute alcohol, the boxes were transferred to equal parts absolute alcohol and xylol for about 30 minutes and then placed in pure xylol to complete clearing. The boxes were next placed in a dish of melted paraffin in the thermostat for two hours. Owing to the xylol present, it was found necessary to change the paraffin or transfer the boxes to another dish of paraffin during the first hour. When first in melted paraffin, the corpuscles float about and show a tendency to adhere to the sides of the box, and to avoid much of this in the final the boxes should be gently shaken a few times during the first half-hour.

The specimens were embedded, paper box and all. The corpuscles were settled in a layer at the bottom of the box, so, when the paper was pulled off, a paraffin block was obtained with them accumulated in one side.

For the sections, the ordinary Minot rotary microtome was used, set at 1 μ. The large corpuscles especially were found to have settled for the most part on the flat, or with their widths parallel to the bottom of the boxes. To obtain sections cut in this plane, the paraffin block had to be arranged with its bottom surface parallel with the edge of the knife. The paraffin ribbon was of course much packed and crumpled and, of course, few if any of the sections could have been of 1 μ in thickness, but setting the microtome at 1 μ was thought to give thinnest sections possible. The sections were straightened and fixed on the slide by the usual water-method, without using albumen fixative. After drying, the paraffin was removed with xylol, the slides transferred to absolute alcohol and then passed through the gradually descending grades of alcohol, 3 to 10 minutes in each, down to water.

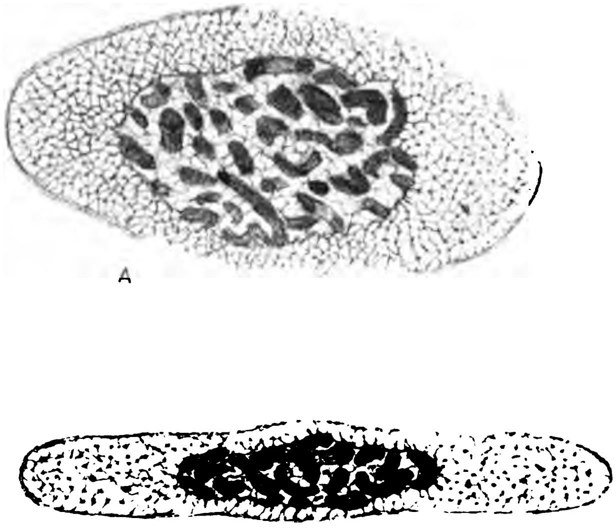
Of the staining methods tried, including gentian violet with safranin, the best results were given by alizarin and toluidin blue. To distilled water was added enough of a saturated solution of the sulphalizarinate of soda in 70 per cent alcohol to make the water a straw yellow, and in this the sections were immersed for about 12 hours. The sections were then rinsed in distilled water and some slides were placed in a 0.5 per cent aqueous solution of toluidin blue to stain nuclear structures. Other slides, in order to study the region occupied by the nucleus in greater detail, were not stained with the toluidin blue at all. The stained sections were then rinsed with distilled water and dehydrated by passing through the gradually increasing strengths of alcohol, 3 to 5 minutes in each, up to absolute, cleared with xylol and mounted.

The action of the fixing fluid and the technique of embedding, etc., when carefully applied, seemed to have produced little change in the shape and size of the corpuscles of the Amphiuma, frog, alligator and snake. Measurements of the sections of those of the Amphiuma, judged truly sagittal by the shape and the position and size of the nuclei, gave an average of 69 μ long by 38.6 μ wide as compared with the average 72.9 μ long and 44.5 μ wide given by the fresh corpuscles. For the blood of all four of the animals mentioned, sections showing the evenly oval contours characteristic of the fresh corpuscles were frequent on the slides and no disturbances of interior arrangement seemed evident in these. Fragments of corpuscles and fragments of sections of them were abundant, but most all such, from their form, were evidently produced by crushing and breaking by the knife in cutting and by the crumpling of the paraffin ribbon. Fragments of sections were often more favorable for the study desired than sections of whole corpuscles. In the sections containing the mammalian corpuscles (guinea-pig and human), there showed much more evidence of distortion both as to contour and internal arrangement.

OBSERVATIONS

The nuclei of the nucleated corpuscles could be best observed as to their position, size, form, and arrangement of chromatin in corpuscles stained whole, after fixation, without embedding. The nuclei in the corpuscles of the Amphiuma and alligator especially appear to consist of a tangled coil of one or more coarse rods of chromatin supported in non-chromatin substances. The coiled and tangled chromatin rods in Amphiuma are very much larger than those in the alligator and, in Amphiuma especially, the peripheral loops of the rods produce a scalloped and lobulated contour of the nuclei quite evident in whole specimens. In the thin sections of stained nuclei, the chromatin rod or rods appear cut into short segments, as shown in figures 1 and 3. A delicate membrane about the nucleus was evident in all the nucleated corpuscles examined, but could be seen only in the thin sections and best in those in which the nucleus was not stained (figs. 2 and 3, B).

A membrane about the entire red corpuscle, after the technique here employed, was distinctly present in the blood of all the animals used. In proportion to the size of the corpuscle, it appeared relatively thicker and more condensed as possessed by the mammalian corpuscles (fig. 4, human). In the thin sections of corpuscles of Amphiuma, this membrane, actually thicker than that of smaller corpuscles, could be resolved under oil immersion objective into an apparently parallel arrangement of very delicate threads. With the fragments of corpuscles, broken and torn by the knife in sectioning and frequently found in the preparations, the nature of the membrane could be better observed than with intact sections. Torn and broken membranes often appeared slightly frayed in the tearing and close study led to the conviction that in Amphiuma, at least, the membrane consists not of a condensation of concentrically arranged parallel threads, and certainly not of concentric lamellae, but instead, of a very deli-



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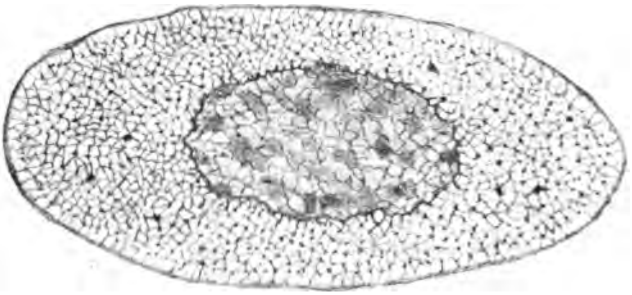

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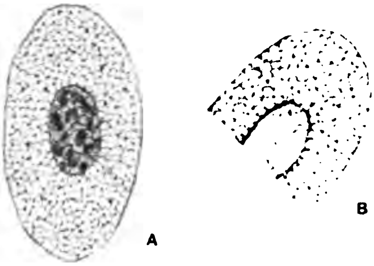
Fig. 1 Drawings from very thin paraffin sections of erythrocytes of Amphiuma means, fixed in the bichromate-formalin-acetic acid mixture and stained with sodium sulphalizarinate and toluidin blue, showing the capsule, reticulum, perinuclear membrane and the coiled rods of nuclear chromatin in stained section. *A*, corpuscle sectioned on the flat; *B*, corpuscle sectioned in profile.

Fig. 2 Erythrocyte of Amphiuma sectioned on the flat and slightly tangentially. Same technique as in figure 1 except that the toluidin blue was omitted. Given to show the full shape of the fixed corpuscle and, especially, the perinuclear membrane and reticulum within the nucleus.



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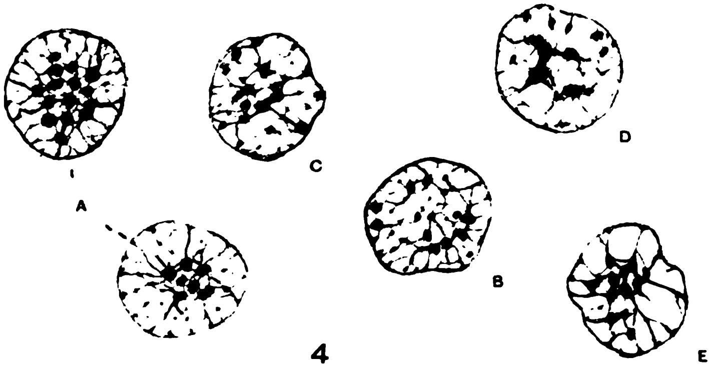

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Fig. 3 From sections of erythrocytes of the alligator (Alligator mississippiensis). Prepared with same technique as figure 1 and drawn in same scale as figures 1 and 2 and to represent the same structures. *A*, section with nucleus stained by toluidin blue; *B*, piece of section from preparation in which toluidin blue was omitted.

Fig. 4 From sections of human erythrocytes prepared with same technique as figure 1, except that toluidin blue was not applied to the sections used for the drawing. Drawn in somewhat larger scale than figures 1 to 3. *A*, two sections of erythrocytes considered as representing more nearly the normal condition of the reticulum, capsule and central knots, with hemoglobin for the most part removed. *B*, erythrocytes with knots more distributed. *C*, *D* and *E*, varying degrees of rupture of the reticulum, presumably produced by diffusion currents set up by the reagents.

cate reticulum so condensed or compressed that its meshes are much elongated and thus produce the impression of a parallel arrangement (fig. 1, A). Meves, describing red blood corpuscles of frog and salamander as showing circumferential fibrils arranged either parallel to the surface or in a continuous skein, must have obtained the same appearances.

A very distinct reticulum is evident in the cytoplasmic areas of the sections and the threads of its meshes are continuous into the membrane. The meshes of this internal (cytoplasmic) reticulum, or stroma of the corpuscle, appear larger in the corpuscles of Amphiuma than in those of the alligator (fig. 3), frog and snake. Corpuscles of the frog and snake, not figured here, gave appearances practically identical with those given by the alligator. In the more transparent sections, those supposedly more free from hemoglobin, the fibrils of the reticulum, though very delicate and varying somewhat in size, appeared distinctly thread-like, and the meshes made by them were angular in form. That the threads of the peripheral meshes grade directly into the peripheral membrane, which itself appears as a condensed reticulum, supports the conclusion that the membrane is nothing more than a peripheral condensation of the internal reticulum and that the membrane could better be called a 'capsule' of the corpuscle. In one of his papers, Meves referred to it as a 'feltwork membrane.' This, and likewise the statement of Růžička that the corpuscle possesses no actual membrane but is bounded by the limits of a fine-meshed reticulum, seem warranted.

In preparations of corpuscles, of Amphiuma especially, in which the hemoglobin was obviously not so completely removed, the component threads of the internal reticulum (stroma) appeared coarser and gave the impression of being rod-like in form, and the meshes of the reticulum appeared oval instead of angular. The oval form of the mesh was due in part to larger knobs or accumulations of substance at the points of junction ('nodal points') of the threads in forming the meshes. Růžička described these knobs in his preparations of frog and mammalian blood as round in form and concluded they represented undissolved hemoglobin. Their larger size in certain preparations here and the apparently larger size of the threads of the reticulum accompanying them is interpreted as due to unremoved hemoglobin adhering to or precipitated upon the reticulum throughout, for such preparations were always less transparent and coarser in appearance and the membrane or capsule of the corpuscle appeared dark and homogeneous as compared with those from which the hemoglobin was considered more completely removed.

All the figures here given are attempts to represent corpuscles considered as having been rendered most free from hemoglobin. The knobs, or junctions of the filaments making the reticulum, appear quite small in these, usually about as large as would be possible were two or more plastic filaments to cross each other in contact and fuse giving an increased amount of substance at their junctions, a knob, or knot of the mesh of the net. In the most clear of the preparations, occasional larger knobs occurred at the junctions of the threads. Several such are shown in figure 2. These larger knobs were usually angular or stellate with their points extending upon the threads joining in them and are interpreted as representing small masses of unremoved hemoglobin adhering upon junction points of a greater than usual number of threads.

In the corpuscles of the Amphiuma, alligator and frog, the threads which join or grade into the capsule at the periphery of the reticulum appear for the most part to join with the capsule at right angles and thus present here a somewhat radial arrangement. The meshes formed by these threads in joining the capsule average somewhat larger in size than elsewhere in the cytoplasm of the nucleated corpuscles. The greater amount of light admitted by these larger meshes compared with the greater density of the capsule gave the impression of a narrow, clear zone about the corpuscle just under the capsule. This was especially true with the corpuscles of Amphiuma (figs. 1 and 2) in which the meshes are larger throughout than in the other nucleated corpuscles examined. Meves observed this radial arrangement of the peripheral filaments of the reticulum in the corpuscles of the frog and salamander, and thought them in regular system similar to the relation of Krause's membranes in the muscle fiber.

Bryce likewise observed it in the corpuscles of lepidosiren larvae, but he considered it a part of a general radial or parallel arrangement of the filaments extending throughout from the nucleus to the periphery of the corpuscle. Our preparations do not show these peripheral filaments to join the capsule in a definitely regular system but at various angles and to form meshes of varying size and shape; nor do the threads of the reticulum extend from the nucleus to the capsule in definitely radial, and certainly not in parallel, arrangements. Only in the thinnest region of the cytoplasm, in the middle of the corpuscle on the flat where the nucleus is nearest the capsule, can threads be traced directly from the nucleus to the capsule (fig. 1, B, section in profile). Here the peripheral zone comprises practically the entire cytoplasm. As Schäfer ('05) suggests, these peripheral threads are only a part of the general reticulum of the corpuscle. Continuous into and stretched from the capsule or membrane, they happen to appear more sparse and regular than the threads of the remainder of the reticulum.

For the larva of Lepidosiren paradoxa, Bryce described in each end of profile views of the corpuscles a small area free of reticulum but occupied by a number of fine dots, and he interpreted these dots as transverse sections of circumferential filaments running in the plane of the flat dimension. Our preparations showed no differences in this respect between sections cut on the flat and profile sections (fig. 1).

As noted above, the chromatin in the nuclei of the corpuscles of the Amphiuma and alligator appears collected into definite coiled rods instead of being scattered in granules of varying size throughout the nucleus. Preparations in which the nuclei are stained differentially do not show a sharp, dark-staining membrane bounding the confines of the nucleus as is found in certain other tissue cells where such is probably due to chromatin material being involved in or adhering upon the nuclear membrane. On the contrary, the nuclear membrane appears here to be another but thinner condensation of the reticulum or general framework, being comparable in origin and structure with the capsule, or membrane, about the corpuscle. The threads of the cytoplasmic reticulum grade directly into it and it stains in the same way as the threads of the reticulum. It could best be studied in preparations to which a nuclear stain had not been applied (fig. 2 and fig. 3, B). Figure 2 represents a slightly tangential section of a corpuscle of Amphiuma on the flat. In such corpuscles, with nuclei not differentially stained, it could be noted that the threads of the reticulum grade directly into the nuclear membrane, that the meshes become suddenly smaller or more dense to produce it and that the membrane carries the same stain-reaction as the reticulum. In other words, it is here suggested that the nuclear membrane is but a peri-nuclear condensation of the general framework of the corpuscle. Sections of corpuscles in profile (fig. 1, B) show the threads to serve as continuations between the capsule and the nuclear membrane.

Furthermore, our preparations suggest that the general reticulum, or framework, is continuous into and throughout the nucleus, contributing to the support of its structures. Figures 1, A, and 2 and 3, B, are attempts to show this suggestion. In such corpuscles, the very thin sections showed the delicate filaments extending from the nuclear membrane and forming a reticulum throughout the nucleus. The meshes of this intranuclear framework seemed somewhat larger than the average of those in the cytoplasm, and especially large when containing a segment of the coiled chromatin rod. The threads stained just as those of the cytoplasm and the membranes. Knobs at the junction points of the threads could not be observed as so definite nor so large as in the cytoplasm, probably due to some extent to the necessarily more obscured nuclear area. The suggestion that the cytoplasmic reticulum is continuous and identical with the nuclear reticulum is somewhat supported by the frequently presented view that the spongioplasmic reticulum of the general cell structure is identical to (stains the same) and is continuous with the karyoplasmic reticulum, or nuclear linin.

The chemical composition of either or both of the reticula, including the membranes, may be that of a nucleo-proteid or lecithin or cholestrin, but in our preparations it occurs in the form of a network in whose meshes is supported the remaining cell load, including the hemoglobin and the nuclear structures. Schäfer states that substances dissolving lecithin or cholestrin will produce an increase in the permeability of the membrane. Bryce thinks that the peripheral capsule ("peripheral ring or band," he calls it) is due to a condensation or massing of the meshes of the reticulum, and he suggests that the filaments of the reticulum are not necessarily fixed fibers but that they may be of colloidal nature. Taking all into consideration, he thinks the reticulum is not an artefact but an actual protoplasmic framework. Citing Bütchli's "Foam theory" of the structure of protoplasm, and noting that the meshes of the reticulum are larger than the limits given for the protoplasmic alveoli of this theory, and much larger than the meshes described for the cytoplasm of leucocytes, Bryce thinks that if the protoplasm of the erythrocyte may at one time have been alveolar in structure, the reticulum could be later derived from a vacuolated condition in which the hyaloplasm of the cell is greatly reduced and the alveolar arrangement lost by the breaking through of the walls of the alveoli. Růžička thinks the observed reticulum is not artefact but an actual structure, that its meshes and the knobs at the junctions of the threads are not coagulation products, for the meshes are too fine and uniform and the threads are not arranged as are coagulum filaments; that the hemoglobin is carried dispersed in the meshes of the net to the periphery of the corpuscle, that the net is the vegetative part of the corpuscle and the hemoglobin the functional part.

Whatever the chemical character, our preparations seem to support the conclusion that the structures observed are not artefact, that the corpuscle is pervaded by a true reticulum, a network of threads joining each other throughout and extending in all the planes of space. That the threads of the reticulum observed serve as a supporting framework of the corpuscle and possess a certain amount of elasticity is suggested by several observations on the living red blood corpuscle: (1) the mammalian corpuscle, after losing its nucleus, remains thinner in its center from which the nucleus was lost; (2) a living corpuscle may be cut in halves and neither half suffer exudation of its content; (3) corpuscles in the circulation may be elongated and their usual shape considerably distorted in passing through the smallest capillaries but always resume their shape upon reaching the larger vessels; and (4), in this laboratory, by tapping under the microscope the cover-glass upon fresh mounts of corpuscles of the Amphiuma, the nuclei could be made to shift considerably from their normal position, moving back and forth with the tapping, sometimes being slightly spread by the pressure, but, the pressure removed, they would resume their normal position and size in the center of the corpuscle floating in the plasma.

With human corpuscles, the technique here employed was not altogether as successful as with the nucleated forms. The stained sections showed more distorted contours and internally ruptured corpuscles than those of Amphiuma, alligator and frog blood prepared in the same way. In the latter preparations, evidences of rupture produced by the reagents used were somewhat rare. Figure 4 is given to represent appearances found in the preparations of human corpuscles. Blood from the guinea-pig gave the same appearances. The two corpuscles farthest in the left (fig. 4, A) represent the form most common in the preparations and, showing less distortion in contour, were the form considered as most nearly representing the normal. The remaining four corpuscles were selected as an attempt to illustrate, progressively, appearances of injurious effects produced by the reagents.

It may be noted that the capsule, the sharp peripheral border of the corpuscle frequently mentioned in the literature, is here relatively thicker and more densely staining than that of the Amphiuma. This may be due in part to a less complete extraction of the hemoglobin considered evident in the interior. The threads of the reticulum, while grading into the capsule and continuous with each other throughout the corpuscle, do not present so nearly uniform size as in the other forms studied. Filaments much thicker than others appear to radiate from the central region, while attached to these are numerous smaller threads joining throughout and completing a general reticulum. At the junction of the larger filaments with the capsule there usually appears a visible knob, or hillock of attachment. One gets the impression in close study that the smaller, probably the normal, meshes are themselves crossed by still finer threads, while a larger mesh may appear perfectly clear. Fine knobs show at the junction or nodal points of the threads, varying in size with the size of the threads.

In the corpuscles considered more nearly normal (fig. 4, A), the frequently described large knobs dispersed in the central region of the corpuscle comprised the most prominent feature in our sections. These appeared approximately spherical in shape and uniform in size and the number observed varied from 17 to 6, a variation due no doubt in part to the planes in which the corpuscles were sectioned. In sections in which the knobs were less darkly stained, one could get the impression, under highest magnification, that these knobs themselves are fibrillar, that they are knots or condensations of very fine threads. If they carry any nuclear material (they have been called the nucleus of the mammalian erythrocyte), our sections suggested it very doubtfully that any stain reaction of a chromatin character is retained in them. Aniline nuclear dyes, such as gentian violet, and even hematoxylin may be retained in them longer than in the threads of the reticulum, but the color will wash out, and the fact that it is retained in them more deeply at times is considered due (1) to their greater compactness of mass holding more of the dye than the smaller and looser structure, but indifferently nevertheless, and (2) to unremoved hemoglobin being entangled within them. They were always darker than the filaments, but this is to be expected, due to their greater density obscuring the light. Occasionally the knobs or knots appeared more scattered throughout the corpuscle and then to vary more in size, as shown in B of figure 4.

The larger filaments, those usually described and which appear more or less radially arranged, are here considered as artefact. Corpuscles manifestly ruptured internally by the action of the reagents (fig. 4, E) show large, clear, vacuole-like meshes and these are always bounded by the thick filaments. It is suggested that these large clear meshes represent areas of the reticulum ruptured by diffusion currents of the fixing agent or alcohols in preparation, and that the broken threads of these areas have been washed together or condensed to form the thicker filaments. Often the latter give the impression that they themselves are composed of finer threads. They occur more or less radially between the centrally placed knots and the capsule probably because these knots are the firmest fixation points.

As to the knobs or knots ('nuclei') of the central region, we beg to suggest the possibility that they may represent remains of an originally existing membrane about the nucleus and of a reticulum within the nucleus of the erythroblast, or nucleated stage of the mammalian corpuscle, similar to those found in the nucleated corpuscles of the Amphiuma and alligator; that the knots represent the remains of these resulting from or after the disturbance of the central reticulum at the time the nucleus disintegrated or was extruded, and that their density may be added to by hemoglobin retained in them.

The membrane or capsule of the erythrocyte, derived as a peripheral condensation or massing of the reticulum, must be the most resistant part, the structure last to rupture under stress. It is permeable, as is well known, allowing a ready diffusion through it. The fact that the mammalian erythrocyte assumes a spherical form before bursting, when swollen and distended by excessive endosmosis in the action of distilled water or weak acetic acid, for example, may be explained as due to its less resistant internal framework being first torn asunder and destroyed by the diffusion currents and the stress. The erythrocyte then becomes a mere turgid sac, the capsule itself rupturing at continued pressure. Both the capsule and framework are dissolved by alkalies.

The red blood corpuscle is a tissue element extremely differentiated in structure for the performance of an extremely specialized function. In the mammal it is more differentiated than in the lower vertebrates, being one of the two bodies possessed that, containing no nucleus, can no longer be called a cell. From the above studies it is concluded (1) that it normally possesses a framework in the form of a fine threaded, somewhat elastic reticulum in the meshes of which its hemoglobin is supported so intimately that its content partakes of the physical characters of gelatin; (2) that in the nucleated forms, this same reticulum is continuous into the nucleus, supporting its structures; (3) that it possesses a peripheral membrane or capsule into which the threads of the reticulum grade and which is derived from and consists of a peripheral condensation or massing of the reticulum; (4) that there is a similar but thinner perinuclear condensation of the reticulum bounding the confines of the nucleus and forming a nuclear membrane of the nucleated forms, and (5) that the central knots, or "nucleus of the mammalian corpuscle," are masses of the material of the nuclear membrane and reticulum originally existing in the central part and result from or after the disturbance of the interior produced by the disintegration or extrusion of the nucleus.

Finally is due an expression of appreciation of the kindness of Professor Hardesty at whose suggestion and with whose guidance and collaboration this study was made.

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THE GROWTH OF THE HEAD AND FACE IN AMERICAN (WHITE), GERMAN-AMERICAN AND FILIPINO CHILDREN[1]

BY ROBERT BENNETT BEAN

MATERIALS

146	Filipino girls	Manila, Philippine Islands.
579	Filipino boys	
309	German girls	Ann Arbor, Michigan.
324	German boys	
412	American girls	
415	American boys	
2,185	Total.	

THE GROWTH OF THE HEAD DIAMETERS[2]

Between the ages of six and sixteen the head grows in length least, 0.9 cm., in the American girls, and most, 1.6 cm., in the Filipino boys; in breadth least, 0.5 cm., in the American girls, and most, 1.1 cm., in the German boys; and in height least, 0.5 cm., in the German and American girls, and most, 1.1 cm., in the Filipino boys. The heads of the Filipinos grow more rapidly in length between six and eleven years of age than between eleven and sixteen years of age, whereas the heads of the Germans and Americans grow more rapidly in the latter than in the former period. What is true of the Germans and Americans in relation to the Filipinos is also true of the boys in relation to the girls.

The head size as represented by the module (length plus breadth plus height) increases least, nineteen points, in the American girls and most, thirty-five points, in the Filipino boys.

At six years of age the heads of the Americans of both sexes are the largest, the heads of the Filipinos are the smallest, and the heads of the Germans are nearly as large as those of the Americans. At sixteen years of age the heads of the Filipinos are the smallest, and the heads of the Americans are nearly as large as those of the Germans.

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[1] Presented first at the New Orleans Academy of Sciences in 1914; read by title before the Anthropological Association at Philadelphia.

[2] Length, breadth, and height.

The cephalic index decreases with age for the length breadth index least, 0.0, for the Filipino girls, and most, 3.3, for the Filipino boys; and for the length height index least, 0.4, for the Filipino boys, and most, 2.7, for the German girls.

GROWTH OF HEAD CIRCUMFERENCES[1]

The forehead and occipital regions are large in the boys and in the Americans, the frontal and parietal regions are large in the girls and in the Germans and Filipinos. The forehead and frontal regions together are large in the girls and in the older children and the occipital and parietal regions together are large in the boys and in the younger children.

From six to sixteen years of age, the forehead, frontal, and parietal regions grow most in the Filipinos, less in the Germans, and least in the Americans, but the reverse is true of the occipital region. The forehead, frontal and occipital regions grow more in the boys than in the girls, and this is especially true of the occipital region, whereas the parietal region grows more in the girls than in the boys.

It is notable that, in relation to each of the other regions, the forehead increases in size and the parietal region decreases with age.

The large size and greater growth of the parietal region are characteristic of the girls and of the young children, and the large size and greater growth of the occipital region are characteristic of the boys and of the older children. The Filipinos resemble the girls in this respect, and the Americans resemble the boys, whereas the Germans are more or less intermediate.

The Hypo- types are like the Filipinos, the Hyper- types are like the Americans and the Meso- types are like the Germans.

THE GROWTH OF THE FACE[2]

The growth of the face as a whole may be considered by taking the product of the length and breadth. From this standpoint the growth from six to sixteen years is least in the Filipino girls, greatest in the American boys, with the others in between, the boys greater than the girls. The face increases about 33 per cent. in the girls and about 50 per cent. in the boys during the ten year period.

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[1] Frontal, forehead, parietal, and occipital.

[2] Length, breadth, and facial angle.

The face length increases with age about 2 centimeters in ten years. The girl's face grows more from six to eleven years and the boy's from eleven to sixteen years. The face of the Filipino is shorter than that of the German and American, about 1 centimeter at sixteen years and about 0.3 centimeter at six years. The face of the Filipino grows less in length than that of the German and American from six to sixteen years.

The face breadth increases with age from 11.3 centimeters at 6 years to 13.1 at sixteen years. The face breadth of the girls grows more rapidly from six to eleven and that of the boys from eleven to sixteen. The face of the Filipino is as broad as that of the German and broader than that of the American, and the growth of face is about the same in breadth for the three peoples.

The face index increases with age, the face becomes longer relative to its width, and this increase is greatest in the Americans, less in the Germans, and least in the Filipinos. The increase in the Germans is greatest from six to eleven years and in the Americans it is greatest from eleven to sixteen years.

The facial angle represents the projection of the maxilla, and with increase of age this is greater in the American boys and less in the Filipino boys than is apparent in the German and American girls and the German boys. The Filipino girls have no records made of the facial angle.

CEPHALO-FACIAL INDEX[1]

This represents the size of the face in terms of the head, the latter always 100. The face grows relatively more than the head from six to sixteen years, relatively more from six to eleven in the Germans and Americans and relatively more from eleven to sixteen in the Filipinos. At six years the Filipinos have relatively the largest faces, and the Americans relatively the smallest, with the

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[1] Originated by the author.

Germans in between, at eleven this is reversed, and at sixteen all are about the same.

The cephalic index decreases with age, and it decreases from the Filipinos through the Germans to the Americans. The face index increases with age, and it increases from the Filipinos through the Germans to the Americans. If the process of development recapitulates the progress of evolution then the Americans represent in evolution what the adult represents in development, and the Germans and Filipinos are less mature stages. The Filipinos represent what I have called Hypo-phylo-morphs, the Germans Meso-phylo-morphs (?), and the Americans Hyper-phylo-morphs. In each group may be found adult individuals with varying degrees of development in head and face form, and these I would classify as Hypo-onto-morph, Meso-onto-morph, and Hyper-onto-morph, depending upon the extent of development. Crossing of races has introduced the Phylo- types into nearly all peoples, therefore the six forms may be distinguished among almost all mixed races. Among the white peoples the Hypo- types are rare, but among the Filipinos the Hyper- types are abundant. More white peoples have mixed with the Filipinos than Filipinos with the white peoples.

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SOME EARS AND TYPES OF MEN[1]

BY ROBERT BENNETT BEAN

MATERIALS

1,325	American whites,
2,039	American negroes,
73	American Indians.
171	Alaskan Eskimos.
94	Manila Filipinos.

The present study is a continuation of those made previously on the external ear and physical form of man, and it is more detailed and specific than former studies. It corroborates them in general and in particular, and adds racial distinctions to type differences.

The most important result is the segregation of the Hyper-, Meso-, and Hypo- types from each group, both by the ear form and by other anatomical characteristics. The other result of importance is the differentiation of the races by their ear form. Incidentally skin lines were discovered on all ears, lines that represent the folded over skin tip of the ear, the skin tip which should overlie the cartilaginous tip (Darwin's tubercle) but does not always do so.

The segregation of the types, Hyper-, Meso-, and Hypo-, is accomplished by determining for each ear whether the helix is prominent or not, whether the anthelix is depressed or not, whether the lower helix and lobule turn towards the head or away from it, and whether the tragus and antitragus are everted or depressed. After having determined to which type the ear belongs, then the cephalic index, nasal index, and facial index, of the individual are calculated. The results are found below.

TYPE DIFFERENCES

Hyper-.—In this type of ear the helix is depressed toward the head, the anthelix is prominent—projects beyond the helix—the lower helix and lobule turn toward the head, and the tragus and antitragus are everted and prominent—project beyond their surroundings. The nasal index, facial index, and cephalic index indicate that the type of individual associated with this type of ear has a long, narrow nose, a long, narrow face, and a long narrow head as a rule.

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[1] Presented first at the New Orleans Academy of Sciences in 1914, read by title before the Anthropological Association at Philadelphia.

Hypo-.—In this type of ear the helix is prominent, the anthelix depressed, the lower helix and lobule turn out from the head in the form of a shelf, and the tragus and antitragus are depressed below their surroundings. The nasal index, facial index, and cephalic index indicate that the type of individual associated with this type of ear has as a rule a short, broad nose, a short broad face, and a short broad head.

Meso-.—In this type of ear the helix and anthelix are both prominent, thus forming a double roll near the dorsal margin of the ear, the lower helix and lobule turn out from the head in the form of a shelf, but not to the same extent as in the Hypo- ear, and the shelf, instead of being horizontal, has a gentle slope forward or may be precipitous, and finally the tragus and antitragus have an intermediate position, are neither prominent nor depressed. The nasal index, facial index, and cephalic index indicate that the type of individual associated with this type of ear has a nose, face, and head of intermediate form between the Hyper- and the Hypo-, although the face is larger than either of the two.

Each of the three types may be subdivided into onto and phylo forms, the phylo, the primordial form, and the onto, the derived form. The Hyper-onto-morph, the Meso-onto-morph, and very rarely the Hypo-onto-morph are European, or white, types; whereas the Hypo-phylo-morph, the Meso-phylo-morph, and rarely the Hyper-phylo-morph are types of the negroes, Indians, Eskimos, Filipinos, and other primitive peoples.

At birth the white child is a Hypo-phylo-morph, and as the child develops it passes consecutively through the stages of the Hypo-onto-morph, Meso-phylo-morph, Meso-onto-morph, Hyper-phylo-morph and Hyper-onto-morph, unless development stops at or between one or the other of the types.

There is little doubt that the Hyper-onto-morph is the end product of a hyperactive thyroid gland, the result of rapid differentiation, with slight growth, resulting in a small, active, nervous individual. The Hypo-phylo-morph is probably the end product of great thymus activity, resulting in a more or less complete retention of the infantile condition, whereas the Meso-phylo-morph has great activity of the gonads. The other types are variants of the three mentioned, composites, mixtures, blends or mosaics.

RACE DIFFERENCES

The race differences are of two kinds, measured and descriptive. Only the racial differences of the ear will be considered here.

Measured differences: These are divided into differences in the living and differences in the dead. The ears of only three groups of dead people were measured, American negroes, American whites and Filipinos. By measurements of the total ear length, total ear breadth, ear base, true ear length (Schwalbe), concha length and concha breadth, it is found that the negro ear is short and broad, the white ear is long and narrow, and the Filipino ear is relatively longer and narrower than the white ear.

The ear length and the index of the ear of both the living and the dead are as follows:

DEAD

Group	Ear Length		Ear Index	
	Male	Female	Male	Female
American white	64.18	——	58.0	——
American negro	58.58	58.32	64.0	60.8
Manila Filipino	58.80	57.43	56.8	57.5
LIVING				
New Orleans student	63.9	——	57.4	——
American "old" white[1]	66.9	61.3	55.9	56.0
American Indian	72.3	——	52.6	——
Alaskan Eskimo	73.8	67.1	54.4	53.0
American negro	60.8	58.0	60.9	60.2

Fœtuses, new-born and young infants, male and female:

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[1] "Old" whites are those who have been in this country for three generations or more.

Ear index, white	**68.8**
Ear index, negro	**64.5**

No other measurements are given because racial differences are more pronounced in the ear length and the ear index. The Indian and Eskimo have long ears, the negro and Filipino have short ears and the ears of the white people are intermediate. This accounts in part for the fact that the ear index of the negro is high, that of the Indian and Eskimo is low, and that of the white is intermediate, but it does not account for the low index of the Filipino. The reason for this is that the ear of the Filipino is short and also narrow, it is a small ear. The negro ear is not only short, but it is also broad.

The ear increases its size with age, to seventy years or later, but the increase in length is greater than that in breadth, therefore the index decreases with age.

Descriptive Differences.—The true negro ear is small, almost flat, close to the head, and the helix is broad as if much folded over. The upper part of the helix is almost horizontal and passes directly backward from the upper end of the ear base to join the vertical dorsal portion of the helix at a right or acute angle in a rounded point at the upper outer extremity of the ear. The superior and dorsal borders of the helix are separated by a depression above Darwin's tubercle, where the helix is thin or absent. The dorsal border passes downward and turns forward at an obtuse angle to form the inferior border of the ear which enters the cheek almost at right angles, with no lobule or a very small one which is nearly flat. The Satyr tubercle is well marked and Darwin's tubercle is small or absent. The skin lines formed by the overfolding of the helix are less distinct on the negro ear than on the white, and they usually converge on the negro ear over Darwin's tubercle. The true negro ear is not seen in great numbers among American negroes. It occurred 245 times among 1,478 New Orleans negroes (16.6 per cent.), men, women and children, chiefly of the laboring classes. There is another form of ear that is found frequently among the negroes, but it is also found not rarely among other peoples, even among the whites, and I have called this the involuted ear, because it seems to represent an advanced stage in retrograde development and evolution. It has a gnarled appearance, as if the ear had been burned around the border and had contracted irregularly in healing, leaving a thick, irregular helix. This ear type was at first thought to be due to accidental causes, but the presence of the skin lines of the ear tip in regular order proved the ear to be a true type. It was found 601 times in 1,478 New Orleans Negroes (40.7 per cent.) and 52 times among 857 New Orleans whites (6.1 per cent.).

The details of the ears of the negro and white are different as follows: The negro ears are glabrous, the white ears are hirsute; the Satyr tubercle is large in the negro ear, small in the white; Darwin's tubercle is more difficult to find in the negro ear than in the white; the skin lines converge about Darwin's tubercle in the negro ear, and between Darwin's tubercle and the Satyr tubercle in the white; the helix is broad in the negro ear, narrow in the white; the anthelix is more prominent in the white ear than in the negro; the posterior auricular sulcus is deeper in the negro ear than in the white, and in the negro ear the sulcus dips into the concha, whereas in the white it turns out over the helix or lobule.

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ON THE PROPORTIONS, DEVELOPMENT AND ATTACHMENT OF THE TECTORIAL MEMBRANE

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ELEVEN FIGURES

Some years ago the writer (Hardesty '08) made an attempt to present something of the actual nature of the mammalian tectorial membrane based chiefly upon the study of teased fresh and unshrunken specimens. After learning something of the nature, shape and proportions of this structure in the fresh condition as compared with its appearance in the more usually employed sections of the cochlea, the writer became convinced that of the very numerous observations upon the membrane previously published practically all had been based upon the various more or less abnormal, rather than normal, appearances of it produced by the methods of its preparation for study. Experiments as to the action of the commonly used reagents upon the fresh tectorial membrane showed that under the usual treatment with alcohol in dehydration and the action of clearing reagents it suffers far more shrinkage and distortion than any other structure in the cochlea and perhaps in the entire body. This result of dehydration and clearing was very evident even after the action of fixing fluids which themselves were found to produce but little distortion. For this reason it was concluded that the usual sections of different embedded cochlea, and often different sections of the same cochlea, show the membrane, even in a given locality of its coil, varying greatly in its shape, size and in its position over the spiral organ (of Corti). The hope then suggested itself that something might be contributed to the knowledge of the actual character, shape and proportions of the tectorial membrane by studying it in the fresh condition, by comparing the fresh with teased out membranes acted upon by various fixing fluids, and by experimenting with methods of embedding for sections of the cochlea in which more normal appearances of the membrane might be retained. Cochleae of pigs were used wholly in that investigation, almost entirely from pigs at or near 'term.' Those of one young suckling pig were obtained. The paper made no attempt to cover the process of the development of the tectorial membrane further than to give a brief review of the various publications bearing upon it and then considered as already having well covered the process, and it gave one drawing showing one stage of the development for use in describing the assumed process by which its final structure is acquired and its adult position with reference to the spiral organ is attained.

Since the publication of the above paper dealing with the membrane in young animals, the writer has been occupied in an attempt to construct a model of the auditory apparatus in which the proportions, position and environment of the tectorial membrane in the cochlea are simulated and by which its behavior when subjected to the energy imparted to it by sound waves may be illustrated. In the construction of this model, a further detailed study of the proportions and position of the actual tectorial membrane seemed necessary, and in this study it became evident that the observations should be carried to the membranes of adult animals rather than confined to those in the cochleae of embryos and fetuses. Since several of the results of this further study seem of interest, though some of them are confirmatory of results previously published, and since relatively so few observations upon the adult mammalian cochlea have been recorded, it is the purpose of the present paper to give certain of the findings of a somewhat detailed study of the spiral organ of the adult mammal. The shape, proportions, position and attachment of its tectorial membrane are especially considered. Toward the end of the study, certain points in the question of the attachment and position of the adult membrane and the structure of its surfaces arose in comparing the findings with those recorded for the membranes in cochleae of embryos and fetuses in the paper of the writer and in papers by others appearing since. These points made it desirable to again go over from the beginning the processes by which the tectorial membrane and spiral organ are developed. As bearing upon these points, it is deemed allowable to review here certain steps in the development as now found by the writer, and some drawings illustrating these steps are given.

Another purpose for which this paper is submitted is that it is a necessary anticipation of the study, begun earlier, involving the construction of the model mentioned above, with a view to illustrating the possible action of the membrane as a vibratory mechanism in the process of hearing. A description of the results of this attempt is now in preparation.

In my previous paper, using freshly obtained cochleae of pigs at and near 'term,' it was found that by very tedious and careful procedure it was possible to remove by teasing methods parts of and even the entire tectorial membrane in the fresh state. In the fresh state, the membrane was found to be most inconceivably flexible in nature, to cohere and to adhere to the teasing instruments with a most exasperating readiness, and to have a specific gravity practically no greater than that of the fluid in which it normally lies. It is transparent and its removal was best accomplished over a black stage of the dissecting microscope. Its behavior in the fluid in which it was teased under the dissecting microscope indicated that the fresh membrane possesses barely enough elasticity against stress applied to it transversely to enable it to gradually assume its coil when floating about in the fluid before coming to rest upon the bottom of the dish. Once in contact with the bottom it could not resume its coiled character. On the other hand, it appeared to possess considerably more elasticity against stress applied parallel with its length, more than enough to enable it to maintain its shape in transverse section and certainly enough to maintain its outspanning position just over the hair cells of the spiral organ, whatever the position of the head.

Under the compound microscope, study of both its whole thickness and of torn bits showed it to consist of very numerous fine filaments embedded in a seemingly gelatinous matrix. The membrane being of ectodermal origin, the matrix was considered as a jelly-like form of keratin. The varying directions, length and independent character of the filaments was described and the various other features of the membrane which seemed evident to the writer were compared as they agreed with or differed from the findings of others recorded in the literature. It was further found by experiment that the action of certain fixing fluids of themselves, those containing no alcohol and whose ingredients produced no appreciable exosmotic diffusion currents in tissue elements, caused very slight distortion of the membrane. In Zenker's fluid, for example, the endosmotic and exosmotic effects upon the membrane appeared to be quite evenly balanced and measurements of the dimensions of tectorial membranes after its action indicated that practically no differences from the dimensions of the fresh had been produced. Cochleae could be left in this fluid long enough for decalcification of the fetal bony lamina and thus allow much greater ease and precision in removing this from the membranous cochlea preliminary to clipping the latter away in order to remove the tectorial membrane. After Zenker's fluid, the membrane in the fetus at term appeared more opaque, less flexible, less fragile, and more easily removable entire from its attachment upon the vestibular lip of the spiral limbus. Such fixed specimens could be washed in water, but attempts to dehydrate and clear them always resulted in shrinkage and distortion. Mounts for study had to be made in glycerine or glycerine-jelly.

Measurements of both the fresh and the thus fixed tectorial membranes gave an average length of the membrane, in pigs at about term, of 25.5 mm. In width and thickness it was found to decrease gradually and evenly from its end at the apex of the cochlea, where it is much the largest, to the narrow and thin end of its basal coil, which ceases to project in width beyond the hair cells of the spiral organ. In the first or apical coil, the width of the membrane was found to be such that its outer edge projects considerably beyond the outer hair cells of the organ.

In extent, the tectorial membrane was found to occupy the cochlear duct throughout and to be strictly coextensive with the spiral organ. Thus its length is less than the lengths of the scalae on its either side, especially less than that of the scala tympani. Each of its ends was found to be rounded and to terminate bluntly. Its axial edge thins suddenly and knife-like and is permanently attached upon the vestibular lip of the spiral limbus, being left thus attached by the ectodermal cells, which, at an early stage, ceased to produce it, leaving it adherent to the fibrous mesenchymal tissue comprising 'Huschke's teeth' and the remaining portion of the vestibular lip covered by it. Its outer edge was found to be bluntly rounded and slightly scalloped, as a result of the component filaments curving apex-ward around this edge from the basal surface, and frequently in small bundles, to form the edge. The apical surface was found to be convex and smooth. The immediate convex surface consisted of a thin layer representing the result of the first activity of the then young producing cells below, in which layer or first product the matrix at least had not been so completely produced as later, allowing the first formed ends of the filaments to become tangled or washed, as it were, into an irregular arrangement resembling a reticulum. The remainder of the filaments continued into the body of the membrane, untangled and evenly embedded in the later and more completely produced matrix of the membrane. In transverse sections of the membrane, this immediate surface appears as a darker rind, or so condensed that the filaments cannot be traced in it, and it was referred to as the 'peripheral condensation.' A peripheral condensation likewise appears on the basal surface of the membrane in sections of embedded cochleae. There it was usually thinner and less uniform than on the convex surface but was considered as representing the last and likewise incomplete product of the activity of the cells producing the membrane—the surface left as the cells were ceasing to function and were being torn away from their product in receding from it. The appearance of condensation, or the darker rind, was considered as due to the action of the reagents upon the different character of these surfaces.

The basal surface of the removed membrane, viewed on the flat, showed three lines. The axial one of these was found to be the line of the imprint of Hüschke's teeth, or the line marking the outer margin of the attached axial edge (inner zone) of the membrane. The middle line was found to be 'Hensen's stripe,' a surface marking described by Hensen in 1863. This stripe was decided to be a very slight linear elevation occurring coincident with the line of the interlocking phalanges of the pillars of the spiral organ and thus adapted to the groove or space on the surface of the organ between the hairs of the inner and outer series of hair cells. A peripheral or outer line appeared to be the line of attachment of the outer margin of an otherwise detached or detachable thin layer of the basal surface which was described as an "accessory tectorial membrane." In the apical coils, this line, or outer edge of the accessory membrane, runs considerably axial to the outer edge of the tectorial membrane. This distance however gradually decreases towards the basal coil till the line comes to coincide with the outer edge of the tectorial membrane, or, in other words, the outer edges of the two membranes gradually come to coincide toward the basal end. The evidence of the existence and the description of the structure of this accessory membrane as well as the description of the arrangement of the filaments in the membrane proper were presented in some detail.

As to the attachment of the tectorial membrane, it was shown that the membrane is purely a cell product, wholly non-cellular from its beginning; that during its formation it is of necessity attached to the cells which produce it, and, at any stage of its formation, an incompletely formed region must be and is then attached to the cells completing that region; that its thin axial edge or zone, the region whose production ceased earliest, remains permanently adherent upon the vestibular lip of the spiral limbus; but that, after its production is completed, by actual observation of it in position in teased specimens and in trustworthy sections of it, by the study of the later stages of its formation by the cells concerned, and from the change in position of the spiral organ with reference to its basal surface, the conclusion was reached that the main body or entire outer zone of the membrane does, and by necessity comes to, project entirely free over the spiral organ. Observations of others were cited both as agreeing and disputing that this outer part of the membrane is free, and it was advanced that all the disputing claims are based either upon studies of mammalian cochleae in stages of development before the production of the membrane is completed or upon studies of sections of dehydrated and embedded cochleae in which, due to shrinkage and distortion produced by the treatment, the membrane was shrunken and pressed upon and thus apparently attached upon the surface of the spiral organ.

It was finally urged in the paper that the tectorial membrane and not the basilar membrane (membranous part of the spiral lamina) is the chief vibratory structure in the mechanics of hearing. The principal of the considerations upon which this suggestion was based are the following: (1) The general acceptation that the cochlea is the peripheral organ of the auditory apparatus, that auditory impulses are aroused in the hair cells of the spiral organ, about which cells the telodendria of the auditory (cochlear) nerve fibers terminate, and that these impulses are initiated by the impingement of the hairs of the hair cells against the basal surface of the tectorial membrane. (2) That the tectorial membrane is far more flexible and by structure far more capable and qualified to serve as a vibratory mechanism than is the basilar membrane. (3) That the tectorial membrane varies in its proportions considerably more than the basilar, its thick and broad apical end gradually tapering to its narrow basal end, thus allowing greater possibilities of resonant activities and in wider range. (4) That in development and structure, the basilar membrane is not composed of individual nor independent fibers but is nothing more than a flat tendon whose component fasciculi are intimately connected with each other; and further that even if it were composed of independent fibers, being blanketed on its either side by continuous layers of tissue far thicker than itself, one of which layers is a syncytium, its fibers could not be thrown into vibration either individually or in groups. (5) That the tectoral membrane is always entirely coextensive with the spiral organ while the basilar membrane is not always so. (6) That the position of the tectorial membrane in the cochlea is more logical for the function than is that of the basilar membrane. The tectorial membrane may impart stimuli to the *peripheral* ends of the auditory cells and it also lies nearest the scala vestibuli, that is, to the fluid to which the foot of the stapes transfers directly the energy imparted by sound waves.

The theories in which the basilar membrane is considered the vibrating mechanism of the cochlea were, therefore, deemed untenable and an application of the 'telephone theory' to the tectorial membrane was suggested.

Since the publication of the above paper by the writer, three other papers dealing chiefly with the tectorial membrane have appeared.

The very instructive paper by Held ('09) deals with the development in the cochleae of the rabbit, chick and pigeon. He used embryos and various fetal stages of the rabbit before and after birth and used the fixing fluid which was used chiefly here (see below) for fixing and decalcifying. He describes the tectorial membrane of the rabbit as composed of three layers in thickness and, during development, three zones in width. In the mature stage, he thinks the third or outer zone is questionably distinguishable, and that the only attachment of the membrane is that of its axial edge, or inner zone, upon the vestibular lip of the spiral limbus, the entire outer part being free. Certain of the findings in Held's paper will be referred to in place.

Vasticar ('09 and '10) gives what purports to be a study of the tectorial membrane from fresh and osmic acid fixed cochleae of the rabbit. As far as the anatomy of the membrane is concerned, beyond the statement that it is a "cuticular membrane of extreme delicacy," his descriptions of vertically implanted, independent filaments, like a vertically placed hair brush, the ends of the filaments sometimes showing an 'olivary corpuscle,' that the ends of the filaments give the basal surface the appearance of spiral striations, etc., are so far from structure actually observed and so fanciful as to render his conclusions worthless. He agrees with Coyne and Cannieu ('95) that the outer zone of the membrane is attached to the spiral organ, united by short cuticular ligaments to its cells as far over as the cells of Hensen, and he cites Corti, Claudius, Henle and Lowenberg as supporting this attachment of the outer zone, but states that Waldeyer, Hensen, Ranvier, Retzius, M. Duval, Tafani and others claim there is no attachment of the outer zone.

Prentiss ('13) deals with the cochlea of the pig, using stages from 4 cm. in length up to fetuses at about full term. He advances one new claim. The initial purpose of his paper seems to have been to support the frequently made assumptions of Shambaugh ('07, '08, '10, and '11) and to demolish by controversy suggestions offered by others as to the actual anatomy and probable action of the tectorial membrane. He states his best results were obtained by fixing with 2 per cent osmic acid and with vom Rath's osmic-picric-acetic mixture, claiming that the precipitation of the reduced osmium tetroxide gave a browning of the tectorial membrane by which "its cuticular structure" was sharply brought out. He decalcified before embedding with 5 per cent nitric acid in 80 per cent alcohol and used celloidin sections. A certain amount of decalcification must have been accomplished while in vom Rath's fluid. Later in his paper he refers to having dissected out tectorial membranes by "more favorable methods" than those employed by me and with results which did not support my observations. While in my first experiments in teasing out the fresh membranes I did "crush the bony labyrnth with a hammer," this was not done later and in doing it I doubt that the cochlea was jarred much more than by breaking the bone in another way, nor do I think that, as assumed by Prentiss, the blows necessarily disturbed the normal attachment of the membrane much more than considerably heavier blows on the skull which the function of hearing is able to sustain. While Prentiss's methods of dissection could have been easily far better than mine, one is disappointed in that he gives no description whatever of his more favorable methods and none of the results obtained with them. Through the pages of his paper, he progressively describes the structure of the tectorial membrane as attached by 'delicate threads,' as composed of 'lamellae' (supporting Shambaugh), "parallel fibers or lamellae," "delicate parallel plates," 'a reticulum,' and finally advances the one new claim of his paper, namely, that the membrane is a honey-comb or chambered structure, each chamber corresponding to and produced by a separate cell and that thus the transverse dimensions of the chambers are the same as those of the cells of the greater and lesser epithelial thickenings or ridges of the earlier fetal stages, both of which ridges he claims produce the membrane. The producing cells being situated on the basal side of the membrane, the lengths of his chambers, curving axisward, must extend through the thickness of the membrane. He concluded that the content of his chambers (matrix, Zwischensubstanz, etc., of others) is a fluid "resembling the endolymph."

A claim suggesting Prentiss' contention as to the origin and structure of the membrane was advanced by Coyne and Cannieu ('95), and Prentiss states that I misquoted these authors when I cited their paper as one of those in which a fibrous character of the membrane was suggested. In citing Coyne and Cannieu at the place in question, I had no reference whatever to their idea, which I thought quite erroneous, as to the process by which the membrane is produced by the cells basal to it, but merely to the fact that they considered the structure of the membrane as *"un reseau."* Vasticar ('11) quotes directly a later statement by Coyne in which *"d'aspect areolaire"* and *"la forme d'un reseau"* are again applied to it. I translated *reseau* as meaning reticulum. A reticulum is a net and, in anatomy, is a network whose meshes extend in all planes. A net is composed of threads, not plates nor lamellae, and the word does not convey the idea of walled pockets or alveoli, nor that of a honey-comb structure. Whether, as Coyne states, the meshes (*mailles*) of the reticulum conform to the sizes of the cells of the organ of Corti (*cellules sensorielles ciliees*), which he assumed secrete the membrane, was a question, however doubtful, not in mind at the time. Prentiss uses the paper of Coyne and Cannieu in support of his claim of the chambered structure. He is right in showing that my citing the paper at all in the relation I did was unfortunate. Support of the fibrous character of the membrane alone was sought, and while I find it is fibrous, the normal arrangement of the fibers is not in the form described in the paper.

Prentiss describes the walls of his chambers as coinciding with and continuous with the sides of the producing cells, the cavities of the chambers with the bodies of the cells. His figure 5, drawn from a section of the actual specimen in which the producing cells are cut longitudinally, is given to prove his chambered structure, but in this figure nearly half of the filaments of the membrane are given off from the ends of the cells instead of from their sides. Figure 9 of my paper

('08) represented a thin section after paraffin in which the membrane was cut in a plane parallel to but splitting Huschke's teeth. It showed the fibers near the teeth necessarily cut across, since they curve apexward toward the surface of the teeth, while the plane of section through the body of the membrane was more or less parallel in places with the course of the fibers. That the fibers in this section appeared as washed together, cohering to each other in anastomosing bundles, was explained by me as due to shrinkage and resultant agglutination. But Prentiss interprets this figure as showing his chambered structure, though the sections of the chambers he sees (the meshes of the apparent reticulum of bundles) vary from sizes for smaller than sections of the cells supposed to produce them could be, and the very various shapes of the meshes are questionably similar to what would be the shape of the cells so sectioned. Prentiss' figure 8, a section of the membrane similar to my figure 9, shows some of the larger meshes (sections of his chambers) about ten times the size of the smaller meshes. The cells of neither of the epithelial thickenings or ridges vary so in size. His section merely indicates even more agglutination than mine. As to the endolymph filling his chambers, Prentiss states that I "could not demonstrate by special stains the presence of a matrix which would hold the fibers together." The presence of the seemingly gelatinous or soft keratinous matrix, in which the fibers are embedded, seemed to me one of the most evident features of my preparations of teased tectorial membranes, and its presence and apparent character was described by me as well as by others previously. That I was unable to determine by stains a definite micro-chemical character for it is true.

I described in my teased preparations from the pig a structure which I called an "accessory tectorial membrane." Prentiss states that this probably represented the reticular membrane or lamina of the spiral organ stripped off in the teasing. Whether this structure is an accessory membrane or not, I have found that it likewise appears on the basal surface of the membrane of the adult hog and in places not torn. Prentiss' statement indicates first, that he has never seen it at all in his 'dissections' and second, that his idea of the lamina reticularis is rather peculiar.

My perhaps unnecessarily tedious experience in trying to determine the normal character of the tectorial membrane and in trying to get sections of it showing this character would lead me to suggest it rather impossible to get normal preparations after fixation with osmic acid, whose power of penetration is remarkably poor, or even with vom Rath's fluid, and to get normal appearances would be certainly impossible after decalcifying with 5 per cent nitric acid before embedding. To me, all of Prentiss' figures drawn from the actual specimens show considerable shrinkage, his figures 5 and 6 less than the others. In his figure 9, the distortion of the tectorial membrane, outward and out of shape is very evident. In his figure 10, given as representing the apical coil of a pig at about term, the outer edge of the membrane is badly

Vials, with blank labels on them, and a supply of fixing fluids were taken to the slaughter-house and the cochleae were dropped into fixing fluid as they were removed, the name of the fluid and the stage of the specimens being then indicated on the label.

A series of developing cochleae were finally obtained, beginning with those of fetuses of 3.5 cm. in length (crown rump measurement) and increasing by from 1 to 3 cm. up to fetuses at term. The latter stage varies in length between 20 and 30 cm. and had to be judged by the appearance of the fetus, chiefly by the amount of the hair on the body and the condition of the eyelids. The head of the fetus was removed and split sagittally, the brain cleaned out and, in the older specimens, the cochleae were broken out with the fingers. In the younger specimens, a square of the skull containing the cochleae was cut out, the surplus external tissue removed and the square dropped into fixing fluid. From certain of these, the cochleae could be removed under the dissecting microscope upon return to the laboratory; others, the youngest, were best carried through the procedure and sectioned entire, the plane of section determined by the landmarks of the cranial wall.

Specimens for the study of the adult tectorial membrane in the fresh conditions were placed in amniotic liquor, brought to the laboratory and used immediately. Occasionally physiological salt solution was used to which had been added a few drops of saturated solution of the bichloride of mercury, to check maceration. However, only sufficient fresh specimens were used to obtain a few sets of observations of the fresh tectorial membrane, it having been found in the previous study and verified here that certain fixing fluids, in themselves, distort the membranes very little if at all, and that the membranes may be removed much more easily and with less injury from fixed and partially decalcified than from fresh cochleae.

It was early found that with cochleae whose bony labyrinth was advanced, a greater percentage of normal appearances could be obtained if a small hole was made through the bone at the apex, before or within two hours after placing them in the fixing fluid. In doing this, very great care had to be taken not to deeply penetrate the membranous labyrinth. A pair of very fine pointed, small bone forceps was found better for this than a drill-pointed needle. Even with fluids which decalcify as slowly as those used, the carbonic acid gas usually forms within the labyrinth faster than it can transfuse, and the resulting pressure of the confined bubbles will press the tectorial membrane upon and over the spiral organ, often pressing it in places beyond semblance of its normal shape and position. Such pressure may be relieved through a very small hole in the bone. Here, the holes were usually made immediately after return from the slaughterhouse, holding the cochlea down in a Petri dish under the dissecting microscope and in sufficient of the fixing fluid to cover it.

Of the several fixing fluids tried, two were found to give the best results both with cochleae to be teased and cochleae to be embedded for sections. A fluid was desired which would serve both as a fixing and a decalcifying fluid and which would produce neither shrinkage of the tectorial membranes nor swelling. Gilson's mercuro-nitric mixture, for example, invariably gave distorted membranes in cochleae of late fetuses and of the adult, though fair preparations in sections of cochleae from quite young fetuses were obtained after it. The very small percentage of alcohol contained in this mixture was not deemed sufficient to produce the distortion by extraction of water from the membrane, but some other of its actions did prove unsatisfactory with the older stages. Decalcification after fixation by various fluids was tried with discouraging results. With both the nitric and hydrochloric acid decalcifying fluids, proven with other material, either maceration or distorting shrinkage effects resulted in the preparations. Decalcification after embedding the fixed cochlea in celloidin gave better but not satisfactory results. The celloidin imprisons bubbles of gas both within as well as outside the cochleae and those imprisoned within distorted the tectorial membrane in numerous places along its extent.

Zenker's fluid and the fluid employed by Held ('09) gave the best results. In Zenker's fluid, the swelling action of the acetic acid in it, causing the tissues to take up water, seems to be counterbalanced by the action of the potassium bichromate and bichloride of mercury contained, and both these, in addition to the acetic acid, are slow decalcifiers, as well as fixing agents.

The mixture employed by Held was here made by adding 40 cc. of the commercial (40 per cent) formaldehyde and 50 cc. of glacial acetic to 1000 cc. of a 3.5 per cent aqueous solution of potassium bichromate. This mixture, is at first the color of the bichromate solution, but by warming or after standing a few hours it turns a greenish brown as the result of oxidation processes. It is recommended as best applied after this change begins. While the reaction between the formaldehyde and potassium bichromate must set free some formic acid, and while formic acid, acetic acid and even formaldehyde to a less extent, acting alone, cause the tissues to take up water and thus produce swelling, the mixture with the excess of bichromate seems to produce no swelling of the tectorial membrane nor of the elements of the organ of Corti.

An advantage of both this fluid and Zenker's is that specimens may remain in them for a long period without injury, and it is necessary for the cochleae to remain subjected till the desired decalcification has occurred. Here, the cochleae, brought from the slaughter-house in vials of fixing fluid, were suspended in large amounts of the fluid contained in low cylinder jars with cap covers. The jar, holding about one liter, was filled two-thirds full of the fluid and the cochleae suspended in it near the surface that they might be surrounded by fluid more free from the salts resulting from the decalcification, which salts sink to the bottom. Also they were suspended that they might be subjected to less pressure than if lying on the bottom. The string by which a cochlea was suspended hung over the edge and outside the jar, held in place by the cover, and to the outer end of the string was attached a label when necessary. Adult cochleae required three to four weeks for complete decalcification, the fluid being renewed twice a week. Decalcification sufficient for microtome sections can be judged by testing with a needle, being careful to pierce the specimen in the region of the vestibule. The thinner walls of the bony labyrinth of the cochlea decalcifying first, it is always the thicker bony regions which give trouble with the sectioning knife.

An additional advantage of the bichromate-formalin-acetic mixture is that specimens fixed in it do not require a period of washing with water preliminary to dehydration for embedding. All the drawings given here were made intentionally from sections of cochleae fixed in this fluid.

Dehydration required especial care. Tectorial membranes fixed without distortion are often badly disfigured by the treatment preparatory to embedding. Here no grade of alcohol of more than 10 per cent greater strength than the preceding was used. Further, it was found best to make up the desired grades of alcohol and let each stand before using long enough for all the fine bubbles of air resulting from the mixture with water to pass off. Otherwise these bubbles will collect upon and possibly form within the cochleae. The specimens were transferred direct from the fixing fluid to 20 per cent alcohol. Then, allowing them to remain in each grade from 3 to 12 hours according to convenience, they were subjected in succession to 30, 40, 50, 60, 70, 80, 90, 95 per cent and absolute alcohol. All clearing agents preparatory to embedding in paraffin, especially xylol, were found especially injurious except with the very youngest stages studied. The absolute alcohol was in all cases allowed to act at least 6 hours and then replaced by ether-alcohol and the specimens embedded in celloidin in the usual way.

The celloidin blocks were hardened with chloroform (not with water) and, to obtain transparency of the celloidin, the blocks were first placed in 95 per cent alcohol for an hour or so before the 80 or 70 per cent alcohol in which they were sectioned. Some of the blocks were transferred from the chloroform to cedar oil in which they remained long enough to become cleared, and then sectioned with the knife flooded with cedar oil. The latter procedure, though excellent for orientation, because of the transparency of the blocks, and for ease in sectioning, requires more time before and after sectioning than sectioning in alcohol and it did not seem to give any better results.

For transverse sections of the tectorial membrane, and remainder of the spiral organ, it is necessary that the edge of the knife passes parallel with the axis of the cochlea, and for transverse sections of the shortest or apical turn of the coil of the membrane, only those sections can be used which pass through the actual apex of the cochlea and the diameter of the cochlear nerve at its base. Celloidin sections varying from 10 to 20 micra were studied. The 3.5, 5.5, and 9 cm. stages were also embedded and sectioned in paraffin for thinner sections.

For staining, the sections were passed through the gradually decreasing grades of alcohol and the most generally satisfactory results were given by Delafield's hematoxylin 6 hours or overnight, washing in water, and both decolorizing and counterstaining with Van Giesen's picric acid-fuchsin mixture. Thence the sections were both washed and dehydrated with the increasing grades of alcohol, cleared in creosote and mounted in balsam.

All the drawings here given, except figures 10 and 11, were first outlined in detail under the new Edinger drawing and projection apparatus. By it, inequality of magnification of parts given by the camera lucida are avoided. The outlines of the nuclei and those of many of the cells could be traced. All except figures 10 and 11 were outlined with the same combination of lenses and the same adjustment of the apparatus and thus they are drawn to scale. The drawings were completed with the identical section projected for the outline placed, in each case, under the microscope and studied under high power for corrections and insertion of details.

PROPORTIONS OF THE ADULT TECTORIAL MEMBRANE

The hog, ox and man belong to those species of mammals which possess the flat type of cochlea and the component structures in their cochlea are remarkably similar in form and character.

Wiedersheim ('93) gives the coil of the cochlea of the hog as having 4 turns, that of man as having nearly 3 turns and that of the ox, 3½ turns. Gray ('07) gives the hog as having 3½ turns and man, 2¾ turns. He did not examine the cochlea of the ox. Wiedersheim must have taken into consideration the long basal end of the cochlea which does not take part in the coil. This end represents the direction of the first outgrowth of the cochlear pouch of the embryo. As shown by Streeter ('07) for the human, this first growth of the cochlear duct is straight, the coiling taking place in its further extension. In dissections of decalcified cochleae of the adult hog, it was found here that this basal end is of considerable length, comparable to nearly one-fourth of the basal, the longest turn of the cochlea, and that it not only does not take part in the coil but that its tip curves slightly in the opposite direction as well as basal-ward. Including the uncoiled basal end, the pig's cochlea, were it all coiled, would comprise about 4 turns.

The cochlea of the ox is broader and slightly less flat than those of the hog and man. Measurements taken inside the bony labyrinths gave, as diameters of the basal turn in vertical sections passing through the apex and therefore including little or none of the uncoiled basal end, for the ox 8.4 mm., for the hog 5.8 mm. and for the human 6.7 mm. And, as heights of the cochleae, measurements from the apical side of the scala vestibuli in the apical turn to the basal side of the scala tympani in the basal turn gave for the ox 6.7 mm., for the hog 4.4 mm. and for the human 4.9 mm. In other words, these measurements indicate that the coil of the membranous labyrinth of the ox is approximately 8 mm. broad at the base by 7 mm. in height; that of the hog, 7 mm. broad by 4 mm. in height, and that of man, 7 mm. broad by 5 mm. in height. The figures given are averages computed from measurements under the compound microscope of sections of 5 different cochleae of the adult hog, 4 of the ox and of 2 human cochleae. The sections of the human were not so satisfactory for the purpose as were the others, owing to imperfect decalcification at the time they were cut. However, they were such that the indication that the human cochlea is relatively more flat than those of the hog and ox may be suggested as correct. The two scalae appear relatively larger in the ox than in the hog and relatively larger in the human than in either.

The cochlea of the pig at term appears to be slightly smaller than that of the adult hog. Averages of measurements taken in the same way of cochlea of fetuses at about full term gave 4.8 mm. as the width of the coil at the base by 3.4 mm. in height. Comparison indicates that the greater size of the adult is in large part at least due to an evident increase in size attained by the two scalae. Very probably the total length of the cochlea has increased but very little in the adult. .

The *length* of the tectorial membrane, is somewhat less than that of the cochlear duct which carries it. It does not extend to touch the blind apical end (caecum cupulare) of the duct nor does it extend quite to the end of the caecum vestibulare, the basal end of the duct. And the duct is not so long as the scalae on its either side, especially the scala tympani. It appears from the best that could be gathered from various sections and teased cochleae that the tectorial membrane is quite strictly co-extensive with the spiral organ. Its exact length not being the point in mind at the time the dissections of the adult hog were being made, only three membranes of the adult were teased out sufficiently intact to determine their lengths. Two of these were decided each to have a length of nearly 27 mm. and the outer about 26 mm. The teasing of these' was done after fixation, which is better for measuring since the membrane does not stretch so readily. All three membranes were broken, but the pieces were all saved and could be arranged in order on the slide. Accurate measurement, of especially the apical or most curved turn of the coil, is difficult. It has to be done in segments. Much straightening and attempts to straighten the membrane usually increase the sources of error. The average length obtained from measurements of seven membranes of fetuses near full term and two from young suckling pigs, recorded in previous paper of the writer, was 25.5 mm. Some of those measurements were obtained by the use of a string laid upon outline drawings of the entire membrane, whole or in pieces, projected under known magnification. Allowing for error in measuring it can only be said that the tectorial membrane of the adult hog is probably a little longer than that of the fetus at term, but hardly more than 1 mm. longer.

The *width* of the tectorial membrane varies considerably. It is widest in the apical turn of its coil and tapers thence gradually and regularly to the basal end, the tip of which is its narrowest part. Its position is over the apical side of the spiral organ, its axial zone being attached upon the vestibular lip of the spiral limbus. Its widest portion spans over and projects beyond the spiral organ to an extent of more than one-fourth of its total width. Its narrowest part barely spans the outer hair cells of the organ. Figures 1 to 4 are given to show its varying proportions and its position. These four figures are drawings to scale of the membrane and its environment as it appears sectioned in one side of a median vertical section of the cochlea of an adult pig. Thus the figures represent consecutively sections of the membrane across the 1st, 3rd, 5th and 7th half turns of its coil.

TABLE 1

Giving in micra averages of the total width, the width of the attached axial zone and the width of the outspanning zone of the tectorial membrane of the adult hog obtained from measurements, taken at the intervals of the coil specified, from median vertical sections of five cochleae and of six teased out membranes

		1ST HALF TURN	3RD HALF TURN	5TH HALF TURN	7TH HALF TURN
Sections of cochleae	Total width	554.2	622.5	477.7	302.4
	Attached axial zone	193.8	206.7	206.7	190.0
	Outspanning zone	360.4	415.8	271.0	112.4
		apical end			basal end
Teased out membranes	Outspanning zone	462.0	413.5	243.3	68.5
	Total width	666.0	619.9	450.3	250.5

Measurements of the width of the membrane taken at the above intervals of its coil from stained median vertical sections of five different cochleae of the adult hog and measurements at the same intervals of six membranes teased out from the adult are recorded in table 1. Short segments of the long basal turn of the coil of three of the latter membranes were lost in their removal, but in these cases the loss did not preclude the desired measurements, the basal ends being saved.

In explanation of table 1, it should be noted that, with the different vertical sections employed, the measurements of the width of the membrane could not be taken across the same identical regions of the coil. The celloidin blocks were not oriented on the microtome so that the median vertical sections always involved the same diameter of the cochleae and, therefore, the measurements of the ends of the membrane had to be taken in each case at varying unknown distances from the actual tips of these ends. Owing to the fact that the basal end of the membrane is not coiled, no median vertical section of the cochlea can pass through this end transversely. Manifestly oblique sections of either end could not be used for measurements of width, and transverse sections of the basal end must of necessity have passed considerable distances from its actual tip. With the teased out membranes coiled on the slide, the micrometer scale could be arranged as a radius involving the widest part of the apical end and crossing the other turns at the specified intervals. Afterward could be taken a separate measurement of the basal end, transversely across its narrowest part. The actual termination of each end of the membrane and of the apical end especially, is bluntly rounded. Measurements of the ends were taken near but not involving the rounded part.

Further, it seemed manifest in comparing the teased preparations with the sections that, in the sections the membrane had suffered some shrinkage. Practically all the shrinkage in width occurs in the thicker outspanning zone and especially toward the apical end where this zone is more voluminous. This explains some of the differences in the width of this zone shown in table 1 between the measurements from the sections and those of the teased out membranes. In all the sections of the adult cochleae, the first half turn of the membrane seemed to conform less in shape to what the teased preparations indicated it should be than in other regions of the coil. In the cochlea from which figures 1 to 4 were drawn, the outer edge of the outspanning zone in the first half turn is considered distorted and retracted axisward by shrinkage (compare *OZ*, fig. 1, with fig. 2). In the table as well as in the drawings, it appears less in width in this than in the third half turn. This explanation of the shape of the section of the apical end as due to shrinkage is supported by the study of the tectorial membranes of fetal pigs described in my previous paper. The depressed apical surface of the outer edge of this zone as shown in figures 3 and 4 is also probably the result of shrinkage.

The attached axial zone (*AZ*, figs. 1 to 4) varies but slightly in width in the different turns of the adult cochlea. In the teased preparations, its width could be easily measured from the fact that the line of imprint of Huschke's teeth (*Ht*, fig. 2) upon the basal surface of the tectorial membrane could be seen. In these, its width was found to conform quite closely to the widths obtained by measurements from the sections (table 1). In figures 1 to 4, the width of this zone appears practically uniform throughout and table 1 shows the maximum variation to be but 16 micra, the zone being narrowest in the basal end just as is the outspanning zone. It will be seen below that the attached axial zone increases somewhat in general width between the fetus and the adult hog.

It must be remembered that the basal turn of the coil is much the longest of the turns, has the greatest radius of curvature, and that, therefore, there is a much greater distance or extent of the membrane between the sections of the 7th and 5th half turns than between the 5th and 3rd half turns, and especially greater than between the sections measured of the 3rd and 1st half turns, which latter involve the apical or shortest turn of the coil. Thus, though the proportions of the tectorial membrane may decrease uniformly from the apical to the basal end, one must expect greater differences between the sections and measurements which are taken transversely at the greater distances apart.

To sum up the studies made as to the width of the membrane, with computations from table 1, it may be advanced (1) that the membrane is widest at its apical end and decreases gradually in width toward its basal end, the tip of which is its narrowest part; (2) that the actual total width of its apical end in the teased out preparations is about 415 μ or 2.7 times greater than its basal end; (3) that its attached, axial zone varies very slightly in width, being but very little narrower in the basal end; and finally (4) that, as indicated in figures 1 to 4, its great variations in width occur almost wholly in the width of its thick outspanning zone. As computed from table 1, this zone in the teased out membrane may be about 390 μ wider in the apical than in the basal end, or the apical 6.8 times the width of the basal end. The same computation applied to the measurements of the sections of the membrane give the outspanning zone in the 1st half turn 3.2 times the width, and in the 3rd half turn 3.7 times the width it has in the 7th half turn. That the differences in the width of this zone do not appear so great in the sections as in the teased out membranes, and that its 1st half turn appears less wide than its 3rd half turn, is explained as due to shrinkage of the apical end, especially in the first half turn, during the preparation of the material for sectioning, and to the differences in the regions of the membrane at which the measurements of its width had to be taken in the sections. The measurement of the 7th half turn especially was in the sections of necessity some distance from the tip of the basal end and therefore could not involve the narrowest part of the outspanning zone. Computed from the measurements of the teased out membrane, the width of the outspanning zone in the apical or shortest turn of the coil appears to decrease only about 1 per cent, while in the second whole turn the decrease is 41 per cent, and between the 5th half turn and the basal end, the longest interval between measurements, the decrease is 72 per cent.

This study of the proportions of the membrane suggests throughout that conclusions as to its actual functional shape based upon its appearance in even the best of sections of embedded cochleae are subject to considerable error.

The *thickness* of the tectorial membrane had to be measured wholly from the sections. Obviously, the teased out membranes could not be used for this. Measurements through thickest part of the outspanning zone at the different intervals are given in table 2. The thickest part usually appeared to be in the region of the small ridge on the basal surface known as 'Hensen's stripe' (*HS*, figs. 1 to 3).

TABLE 2

Giving in micra averages of the thickness of the thickest part of the tectorial membrane of the adult hog obtained by measurements at the intervals specified in median vertical sections of five cochleae

1ST HALF TURN	3RD HALF TURN	5TH HALF TURN	7TH HALF TURN
168.6	137.5	112.4	58.5

It may be seen from table 2 that, just as the outspanning zone is widest, so is it thickest in the apical end of the coil of the cochlea. After whatever shrinkage that may have resulted in the preparation of the sections, computations from the table indicate that in the apical end this zone may be 110 μ thicker or about 3 times as thick as it is at the 7th half turn. Between the 1st and 3rd half turns its thickness appears to decrease about 19 per cent, between the 3rd and the 5th half turns about 18 per cent, and between 5th and 7th half turns, the longest interval between measurements, the decrease is about 48 per cent. The smaller amount of decrease between the 3rd and 5th half turns is probably due to irregularities of shrinkage, but this cannot be determined from the preparations used. The drawings, figures 1 to 4, made from a single cochlea show the decrease in thickness between the 1st and 3rd half turn to be least and that the decrease increases progressively between the 3rd and 5th and the 5th and 7th half turns. One would assume from studies of the teased out unshrunken membranes that this latter form of decrease in thickness is the normal one.

The *volume* of the tectorial membrane may be computed approximately from the areas of its transverse sections. Considered the chief vibratory mechanism in the auditory apparatus, variations in the volume of the membrane, or the 'load' it carries, in different regions are the most important of the proportions. Most all of its volume being carried in its outspanning zone, this zone must determine almost wholly the possibilities of vibration of the different regions of the membrane as well as of the membrane as a whole. The axial zone being attached upon the vestibular lip of the spiral limbus and varying very little throughout the length of the membrane, can hardly have much to do with the variations in "natural vibration frequency" of which the membrane may be capable. In trying to compute the areas of the transverse sections of the outspanning zone, it was thought fairer to use for one dimension its width as found in the teased out and unshrunken membranes. Other dimensions had to be taken from the sections regardless of whatever shrinkage the zone had suffered in them. Using the widths obtained from the teased out membranes as the widths of parallelograms, the depths used were averages obtained from six measurements of the thickness of the zone taken upon the transverse sections of the different regions of the coil at about equal intervals between the outer edge of the zone and the edge of Huschke's teeth (*HT*, figs. 1 to 4). The first measurement was taken in each case near the outer edge and the last at the edge of Huschke's teeth. Of the several cochleae used for the purpose, these sections were used which were judged as passing nearest the apical end of the membrane. The areas of section of the outspanning zone in each region were thus obtained by multiplying its width in the teased out membrane by the average of its thickness in the sections.

Proportional volumes of the two ends and variations in the volume of the zone were most desired, and for such, realizing that by any further procedure the results could be only approximate at best, it was considered most feasible merely to multiply the area obtained for the section of the zone in each region by a given short length, say one millimeter of the length of the membrane. The volumes thus obtained vary as the areas of the sections. The areas obtained are as follows:

Transverse section of apical end	61,723.20 square micra
Transverse section of 3rd half turn	43,293.45 square micra
Transverse section of 5th half turn	18,442.14 square micra
Transverse section of basal end	1,719.35 square micra

The volumes of the different regions, computed in the above way, represented by these areas, may be found to show the following proportional relations: (1) A given short length of the apical end of the outspanning zone of the tectorial membrane may be 41.7 times the volume of the same length of the basal end of the zone. The volume of the same length of the 3rd half turn may be 25.2 times, and that of the same length of the 5th half turn may be 10.7 times the volume of that length of the zone in the basal end. (2) Taken from the basal end toward the apex, it may be found that between the basal end and the region of the 5th half turn, the longest interval between measurements, the volume of a given short length of the outspanning zone may increase 90.7 per cent; between the 5th and the 3rd half turns the volume of the same length may increase 57.4 per cent, and between the 3rd half turn and the apical end, the volume of the same short length of the zone may increase 29.8 per cent.

Just as does the width and thickness, so, as to be expected, does the volume of the zone appear to increase progressively from the apical toward the basal end. That the percentage of increase toward the basal end of the cochlea is progressive rather than regular must be due to the fact that, beginning with the basal end, each turn of the coil is longer than the turn apical to it and, therefore, there were greater lengths of the zone between the transverse lines at which the above measurements were made in each succeeding coil from the apical toward the basal. In studies made here of the teased out membranes of the adult hog and in the studies of the membranes of pig fetuses at term, published in the writer's previous paper, the tectorial membrane, and therefore its outspanning zone, viewed as a whole appeared to increase in width with uniform regularity from the basal into the apical end. If the increase is irregular at all, the impression may be obtained that it is less rapid in the basal than in the other turns of the coil. Drawings illustrating the appearance of the teased out membrane are given in the previous paper.

The above variations in the proportions of the tectorial membrane, assumed at least to approximate the normal adult, are thought to further support the suggestion that the tectorial is far more adapted as a vibratory mechanism in the auditory apparatus than is the basilar membrane. Whether in accord with the Helmholtz theory, which involves sympathetic resonance, or with a modified telephone theory, the much greater variation of the tectorial membrane allows for it a much greater scale of activity than seems possible in the basilar membrane. Measurements of the assumed vibratory width of the basilar membrane, for example those by Kolmer ('07), show that its width (length of its supposedly existing vibrating fibers) at the apical end of the spiral organ is only about 1.8 times its width in the basal end. Averages of measurements here made in cochleae of adult hogs, taken from the line at which the auditory nerve fibers (*AF*, fig. 2) disappear into the spiral organ to the outer angle of the scala tympani, give the basilar membrane a width of 257.9 μ at the apical end and a width of 184.8 μ. at the basal end (fig. 4), thus showing it to be about 1.4 wider at the apical than at the basal end. When the measurements were taken at the level of the floor of the spiral sulcus (about at the line *AF*, fig. 1), the width of the thus questionably vibrating part of the spiral lamina was found to be only about 1.9 wider at the apex than at the base. It may be noted in the figures that this latter measurement includes in the basal coils some of the bony spiral lamina. As seen above, the width of the assumed vibratory part of the tectorial membrane, its outspanning zone, is 6.8 times greater at the apical than at the basal end. The basilar membrane does not consist of independent fibers and thus of fibers capable of resonant activity. Ayers ('91) described it as consisting of four layers of fibers, one of which runs at right angles to the other three. In my former paper, the main or radially arranged part of the basilar membrane was shown to be of the nature of a flat tendon, the tendon fasciculi (fibers of the earlier descriptions) being abundantly connected with each other by smaller collateral bundles. Vasticar ('12) said that it consists of six layers. He, however, included the layer of epithelioidal tissue, or syncytical mesenchyme, on the basal surface of the basilar membrane proper and the endothelium lining the scala tympani as layers of the membrane. The basilar membrane proper and the layer of epithelioidal syncytium upon its basal side vary very little in thickness in the different regions of the coil and the little variation is irregular.

POSSIBLE VIBRATION OF THE SPIRAL LAMINA

Variations of the spiral organ (of Corti)

In the adult hog the spiral organ increases in both width and thickness in passing from the basal toward the apical end of the coil of the cochlea. Near the basal end (fig. 4) it may be seen that the spiral organ proper is much thinner and narrower than in the apical region (figs. 1–2). Reading the sections of the organ consecutively in both sides of the median vertical sections of the cochleae, or even reading figures 1 to 4, which represent the organ in one side of a cochlea, it is suggested that the increase in the size of the organ occurs uniformly from base to apex. Measurements of the width and thickness of the spiral organ as it appears in section in one side of five median vertical sections gave the averages recorded in table 3.

TABLE 3

Giving averages in micra of the width and thickness of the spiral organ, as measured in one side of vertical median sections of cochleae of five adult hogs

	1ST HALF TURN	3RD HALF TURN	5TH HALF TURN	7TH HALF TURN
Width	223.3	221.1	208.7	130.0
Thickness	113.1	104.4	85.2	55.4

The measurements of width of the spiral organ, averages of which are given in table 3, were taken from the level of the surface of the epithelium lining the internal spiral sulcus (*ISS*, fig. 2) on the axial side of the organ to the level of the surface of the cells of Claudius (*CC*, fig. 2). The measurements of thickness of the organ were taken from the basilar membrane proper through the middle of the outer hair cells to the vestibular surface of the organ. As shown in figures 1 to 4, the vestibular surface of the organ inclines axisward appreciably in the apical turns, the outer sustentacular cells being higher and forming a thicker ridge than in the basal end. Thus, measurement through the middle of the outer hair cells will give an approximate average of the thickness in each case. The degree of the axial incline of the surface of the organ decreases toward the basal end, at which it is almost absent. Attention is further called to the fact that in the basal end of the coil of the adult cochlea (fig. 4), both the epithelium lining the internal spiral sulcus and that known as the cells of Claudius are considerably thicker than in the more apical regions. The axisward incline of the outer rods of the organ increases slightly in passing from the basal toward the apical end. This is not so evident in figures 1 to 4 as it was in other sections of adult cochleae. Gray ('00), in suggesting a modification of the Helmholtz theory of hearing, noted that the rods of the spiral organ and the hair cells became smaller in passing from the apex to the base of the cochlea.

The resonance theory, elaborated by Helmholtz, was based upon erroneous anatomical descriptions of the basilar membrane by others. Requiring that the membrane be composed of separate fibers of varying length and free to exercise sympathetic vibrations in response to sound waves of varying length imparted to the endolymph, the theory must be abandoned. The basilar membrane not only does not consist of independent fibers, but it is blanketed on both its sides by thick continuous layers of other tissue, the thickest of which is the cells of the spiral organ itself. The telephone theory of hearing, suggested by Rinne in 1865 and Voltolini in 1885, elaborated by Rutherford in 1886 and further by Waller in 1891 and Meyer in 1898, was likewise applied to the basilar membrane. Denying the possibility of the selective or sympathetic resonance required by the Helmholtz theory, it assumes that the vibrations producing sound act upon the basilar membrane as a whole; that the vibration frequencies induced in the tympanic membrane by given sound waves are repeated by such extents of the basilar membrane, beginning at the basal end, as the resistance offered by the components of the apparatus and the inertia of the membrane will allow. At one time in its development, the telephone theory was applied to the cochlea as a whole instead of being confined to the basilar membrane.

Any application of the telephone theory, either to the entire cochlea or to the basilar membrane requires, of course, agitation of the spiral organ and in such a way that the hairs of the hair cells are involved with the basal surface of the tectorial membrane. In other words, the theory must include the possible vibration of the entire membranous portion of the spiral lamina.

I do not desire to dispute the possibility that energy imparted to the cochlea by sound waves may throw into vibration the membranous spiral lamina. On the contrary, the possibility seems to me supported in my experiments with the model referred to above, and by studies of the character of the basilar membrane, and especially by the above observation that the cellular part of the spiral organ increases in bulk in passing from its basal to its apical end. Since the base of the stapes imparts the wave motion to the cochlea at its basal end, since the higher pitches are known to be mediated by the basal end of the cochlea, and since sound waves of greater vibration frequency (higher pitch) are known to be 'damped out' more readily in overcoming resistance than those of lesser vibration frequency, it seems indeed suggestive that the membranous spiral lamina not only gradually increases in width or bulk but also that its chief load, the cellular spiral organ, itself increases from the basal toward the apical end. But, on the other hand, I beg to emphasize the fact, very evident to me, that the tectorial membrane is far more adapted for the vibratory activities required. It is infinitely more flexible than the basilar membrane, or membranous spiral lamina, especially when both are in their position. In my previous study I had opportunity to compare the two when both are teased out and found that even then the tectorial membrane as compared with the lamina is as a strip of thin paper compared with a board. The arrangement of the fibers in the structure of the tectorial membrane, giving it sufficient elasticity against stress applied longitudinally to enable it to retain its position close upon the spiral organ but giving it practically no resistance to stress applied transversely, renders it peculiarly adapted for undulatory motion. The vibrations are imparted by the base of the stapes by way of the fenestra vestibuli (ovalis), first to the fluid in the scala vestibuli, which scala is on the apical side of the spiral organ. The tectorial membrane projects over the apical side of the spiral organ and therefore is in the logical position for being most readily disturbed by the motion imparted. Finally, among other advantages, the tectorial membrane varies far more in its proportions than does the membranous spiral lamina and especially more than the basilar membrane. In width, its vibratory or outspanning zone is about 7 times wider in the apical than in the basal end while the width of the apical end of the supposedly vibrating part of the spiral lamina is only about 1.4 times its width in the basal end. The differences between the volume of the two ends of the tectorial membrane very evidently exceed those of the lamina to a much greater extent than do the differences in width, and variations in volume are the most important for the functions ascribed to the membranes in the telephone theory.

It has been computed that the actual force of the vibrations of the tympanic membrane, produced by sound waves, is increased about 30 times as repeated in the vibrations of the base of the stapes, and that the amplitude of certain waves as imparted to the tympanic membrane may be reduced as much as 76 times in their transference to the base of the stapes. Both force and amplitude are decreased in overcoming resistance in the cochlea. It is quite possible that very strong sound stimuli may throw into vibrations both the tectorial membrane and the membranous spiral lamina while the less strong and more ordinary stimuli affect the more adapted tectorial membrane alone. If the two were equally affected by the given strong stimuli, their resultant movements would be parallel and the required stimulation of the hair cells in the way usually supposed would not occur. If, however, the position and greater flexibility of the tectorial membrane should result in greater excursion or amplitude of vibration in it than in the lamina, then the hair cells could be stimulated in the way supposed and in accord with the vibration frequency of the wave motion applied. It might be advanced that vibration of both the tectorial membrane and the membranous spiral lamina in case of very strong sound stimuli would be an economical arrangment in the structure of the cochlea. By such, the tectorial membrane, whose motion alone actually stimulates the hair cells, may in these cases be kept within working distance of the protruding hairs, or by such may be obviated injuriously forcible impingement of the tectorial membrane upon the hairs, which might result from extraordinarily great excursions produced in it by the strong stimuli, were the lamina to remain undisturbed. In the more ordinary and less strong sound stimuli, amplitudes and vibration frequencies must occur which are incapable of throwing the lamina into vibration at all but which may affect the tectorial membrane, its excursions decreasing, with the strength of the stimuli, to the functional limit of the auditory apparatus.

I hope to discuss more fully the probable action of the tectorial membrane with a description of experiments with the model referred to above.

STRUCTURE OF THE TECTORIAL MEMBRANE

In the study of the tectorial membrane of the adult hog, I have found little reason to modify the conclusions drawn in my previous paper as to structure from its study in cochleae of fetal pigs. It consists of fibrils or filaments of very varying lengths imbedded in a gelatin-like, probably keratinous, matrix. The directions in which its fibrils are arranged result from the gradual changes in position and the increase and decrease in number of the individual cells which produce its fibrils. The greater epithelial ridge, which produces the membrane, grows thicker, wider and longer for a considerable period after it has begun production, and then recedes in thickness and width and finally disappears as a producing structure. The axial side of the ridge ceases to grow and its cells cease to produce the membrane earlier than the outer side of the ridge. Thus the fibrils of the axial side of the membrane are the shorter and merely curve, from the basal side axisward, due to the growth in width of the ridge, and apexward from the cells producing them. The fibrils of the outer side of the membrane are longer and curve outward, apexward and axisward from the basal side, claimed as due to first the great increase in width and then the decrease in width of the greater epithelial ridge, both of which changes in width occur after the beginning of the membrane.

From the study of the adult, I see no reason for describing the tectorial membrane in more than two zones, the attached axial zone and the outspanning zone. To let Hensen's stripe mark the boundary of a third zone is, I think, unnecessary other than that the stripe forms the axial boundary of that width of the membrane which projects beyond the interlocked phalanges of the pillars of the spiral organ. A 'border plexus' or a thin outermost zone does not exist in the adult nor in the older fetuses. The outer edge of the membrane is bluntly rounded and, in contour, slightly scalloped. The fibrils forming the edge curve from the basal surface outward, around the edge and then apexward and axisward. The appearance described by me as an "accessory tectorial membrane" in the fetus is present on the membranes of the adult hog. In one specimen of the teased out membrane it appeared partly lifted away from the basal surface in places but in none of the mounts from the adult was it so completely lifted away from the main body of the tectorial membrane and so separately visible as in the specimen from the fetus described and illustrated in the previous paper.

Held ('09) described the thickness of the tectorial membranes of the rabbit as composed of three layers: A 'Decknetz' on the apical surface; a middle fibrillar layer on the main body of the membrane composed of fibrils embedded in a matrix (Zwischensubstanz), and a thin homogeneous layer bounding the basal surface. All three layers come together in the outer edge of the membrane which he calls 'the selvage' and which he describes as blunt and irregularly fibrous. By irregularly fibrous is meant that bundles of fibrils curve around the selvage giving it the lobed or scalloped appearance in contour mentioned above. His descriptions of the course of the fibrils and their abundance conforms in the main with mine.

Upon looking at Held's figures of his Decknetz I felt sure at first that he was describing the structure I referred to as an accessory tectorial membrane with its regularly arranged fibrils washed together and cohering in irregular bundles, making his net, and that either he had mistaken it to be on the apical surface or I had been mistaken in thinking it on the basal surface of the tectorial membrane. In his description of it and in his figures, the outer border of his Decknetz is shown to be thicker and its meshes finer than in other parts. The 'accessory membrane' might appear thus if its fibers were disarranged by the treatment. He thinks the 'bars' of his net are assembled from finer fibrils and states that the direction of the bars in places conforms with the direction of the fibrils in the fibrillar layer or main body of the membrane below. However, he describes his Decknetz as extending on the apical surface of the membrane from and usually involving its outer edge, over the entire outer zone and upon the axial or inner zone which is attached upon the vestibular lip of the spiral limbus. While one of the two systems of fibers in my accessory membrane appeared to conform with the direction of the fibers in the main body of the tectorial membrane, the latter being crossed at very acute angles by the other system, only in the basal turn did the outer edge of the accessory membrane seem to extend to the outer edge of the main body, and only in the basal turn did its very delicate axial edge seem to me to extend further axisward than the line of Hensen's stripe. As seen by Held, his Decknetz is considerably wider. He states that he could not follow it completely over the attached axial zone because of the density of this region.

Held's homogeneous layer bounding the basal surface of the tectorial membrane is, I think, nothing more than the finely granular and faintly fibrous pale staining layer found by Rickenbacher ('01) for the guinea-pig after decalcification with nitric acid and staining with eosin. After the procedure used by me, both in the previous and in the present studies, to obtain sections of the membrane, the stain I used shows a thin more densely staining layer bounding both the apical and basal surfaces. I described this as a peripheral condensation of the substance of the membrane (*PC*, figs. 1 to 3) and explained it as representing, on the apical surface, the product of the first activities of the then young producing cells, and on the basal surface as the last product of the then declining activities of the producing cells. That it appears condensed as compared with main body of the membrane, I thought due to the different actions of the reagents upon these superficial and less completely formed products of the beginning and waning functions of the cells. As noted by Held for his homogeneous layer, the peripheral condensation is not so noticeable along the axial side of the basal surface. Here the maturely active cells are probably torn from their product more suddenly than from the thicker part of the outspanning zone. Also, as noted by Held, the very thin extreme axial edge of the attached axial zone appears dense in the preparations. This edge corresponds to only the earlier product of the activities of the cells, for here production of the membrane ceases in the early fetus and the cells sink back into inactive form while the remaining are still forming the 'peripheral condensations.' I have called attention to sections of the apical surface cut parallel to it, showing a coarse reticular arrangement and have suggested that the reticulum in these sections represented the first formed ends of the fibers of the membrane, not so adequately embedded in matrix as in the main body, washed together and cohering in anastomosing bundles. In the transverse sections, these form part of the peripheral condensation. If this suggestion is possible, it could explain Held's Decknetz of the apical surface.

Held did little more than look over the figures given in my paper. He kindly gives a 'Zusatz' at the end of his paper in which he states that he did not know of my paper till after his manuscript had been closed, and that he thought some of my figures defective, two of them 'artificial monstrosities' of the tectorial membrane resulting from swelling. Held had never studied the tectorial membrane of the hog, which I think is similar to the human. All the drawings of the present paper are intentionally made from projections of sections of cochleae fixed and prepared for sectioning according to the identical procedure used by Held for his sections of the cochleae of the rabbit. In so far as possible, I judge my preparations were no more shrunken than were his. Judged from measurements and the appearance of the teased out membrane, I am quite sure they were not swollen. I have not studied the tectorial membrane of the rabbit. He frequently referred to the tectorial membrane of the adult rabbit but, unfortunately, does not figure it. His figure 17, six days after birth, is the oldest stage he exhibits in the rabbit. The rabbit being one of the rodents in which parturition is comparatively premature, his six day old rabbit was scarcely more developed in than a pig fetus about term.

ON THE DEVELOPMENT AND ATTACHMENT OF THE TECTORIAL MEMBRANE

The essential steps in the development of the spiral organ and its tectorial membrane were worked out by Corti himself in 1851 and by Kölliker in 1861. Many other papers have dealt with phases of the process, repeating and adding to the findings of Corti and Kölliker, the most recent being those of Held and Prentiss. Permission is asked here merely to review the process as to its bearing upon two points: the position which the tectorial membrane acquires in its maturely functioning condition and the attachment it retains. As indicated in my previous paper, both these points have been touched upon repeatedly without agreement in results. The most recent papers fail to agree upon them. I have here tried to contribute quantitatively something as to the growth changes in the width of the membrane, and as to the growth changes resulting in its adult position with reference to the cells of the spiral organ and also resulting in the one attachment it retains in the hog.

In the hog, the length of the fetus is but an approximate criterion of the stage of the development of its cochlea. Fetuses obtained in California, for example, I have found average longer at a given stage of the spiral organ than do fetuses from hogs raised in Louisiana. The hog brought to the slaughter-house averages larger in San Francisco than in New Orleans, due no doubt to differences in breed and feeding, for very probably the Louisiana hogs average older and smaller at killing than those in California. All the fetuses here used were obtained in New Orleans.

In fetuses of about 5 cm. (fig. 5), the coiling outgrowth of the cochlear pouch has already acquired nearly three turns. Only the first indications are then appearing of the liquefaction of the mesenchyme, the progress of which gives the scalae on the two sides of the cochlear duct. Along the basal side of the cochlear duct the epithelium has already become much thicker than that of the apical side, but as yet there is no differentiation of the epithelium into the greater and lesser epithelial ridges of the later stages. Upon the axio-basal surface of the epithelium of the cochlear duct appears the beginning of the tectorial membrane (*TM*, fig. 5), being produced by the thicker epithelium. In the sections of embedded material, this product appears densely but finely fibrillar. The fibrils may be seen continuous with the apical ends of the long cylindrical cells, but in the whole product they appear very much tangled and matted together as though an interfibrillar substance were insufficient in either amount or quality to individually support them. When compared with the body of the membrane of the later stages, one receives the impression that the fibrils here, which represent the apical ends of the fibrils of the later stages, are smaller than in the later stages. As may be noted by comparison with the figures following, the extreme axial edge of the young membrane (*AZ*, fig. 5), though very thin, is almost as thick as it is in the later stages. The cells producing this edge never become higher, never become so actively productive of the membrane as those of the remainder of the thick epithelium, and they grade into the non-productive cells of the duct. The outer edge of the young membrane is likewise thin at this stage, the cells producing it grading likewise from the less productive into the non-productive cells. However, the outer edge of the thicker epithelium grows in width and activity along with the rest of the thickening. The entire thickness of the tectorial membrane so far produced in figure 5, only represents a part of the width of what I have called the peripheral condensation on the apical surface of the sections of the further developed membrane, or it perhaps represents a part of Held's Decknetz.

In the outer side of the thick epithelium, there usually appears at this stage a lighter area (*L*, fig. 5) resulting from the nuclei here being placed farther away from the apical ends of their cells. Comparison with later stages (figs. 6 and 7) suggests that this area represents the outer margin of the greater epithelial ridge.

In fetuses of about 8 cm., the increase in number of the cells in the epithelium of the basal side of the cochlear duct has rendered the thicker epithelium there still thicker and wider, and has also resulted in a second but lesser thickening along the outer edge of the first. At this stage the cells of both the greater and the lesser epithelial thickenings, or ridges, are engaged in the production of the finely fibrillar, tangled structure characteristic of the first and seemingly imperfectly formed part of the tectorial membrane. The cells of the lesser ridge, which later become differentiated into the elements of the spiral organ, seem to retain but a very short time this tendency to produce fibrils similar to that of their adjoining neighbors of the greater ridge, along with whom they have developed. While producing fibrils, they are never as actively productive as even the cells of the extreme axial edge of the greater ridge, and their product is more sparse and less mature than even the first product of the greater ridge. They represent the edge of the productive grading into the non-productive cells, and, as they differentiate into the cell elements of the spiral organ, they cease production altogether.

In figure 6, from a pig fetus of 9 cm., the first evidence in my series of the differentiation of the elements of the spiral organ is shown. The first to be distinguished is the series of inner hair cells (*IAC*). While in some sections of this stage and earlier, there may appear shrinkage cracks between the cells of either of the ridges, the beginning of the spiral tunnel has not appeared at this stage, though Prentiss represents the tunnel in his figure of the second turn of a pig of 5.5 cm. Figure 6, as does each of the figures following, represents a section through the 3rd half turn (the first half of the 2nd turn) of the coil. Development and differentiation begins in the basal end and preeedes toward the apex. Therefore a section through the basal turn would show a more advanced stage of development.

The tectorial membrane in figure 6 has thickened so that a main body and an axial edge may be easily distinguished. The beginning of the invasion of the axial edge of the greater ridge by the mesenchymal tissue to produce the vestibular lip of the spiral limbus may be seen. Soon the cells of this axial edge, involved in mesenchyme, will cease to produce tectorial membrane, the cessation at the extreme edge having already begun. The outer edge of the body of the membrane is bluntly rounded and coincides with the outer edge of the greater ridge producing it. Attached upon this outer edge of the membrane are the few fibrils produced by the cells of the lesser ridge.

The amount of the fibrils or fibers produced by the lesser ridge reaches its maximum in pigs between 8 and 14 cm., depending wholly upon the extent to which the elements of the spiral organ have differentiated. The change of character of any of the cells of the ridge into that of any of the various elements of the spiral organ once established, those cells cease to produce the fibrils, become devoted to a different function. From the first they are never more than the outer border of less active cells grading into the non-productive type of the rest of the duct. These fibrils are always more sparse and appear to be supported by a far less amount of the interfibrillar matrix than those of the membrane proper. Further, the amount of the fibrils varies considerably in different individuals in the same stage of development. Figures 6 and 7 (*LF*) show an amount maybe a little greater than an average in my preparations from pig fetuses. Prentiss must have found a greater amount in the pig than any of my preparations show, especially in his figure 6 (pig of 13 cm.), which shows the product extending well over upon the cells of Claudius and relatively thick, considering that it shows the effect of considerable shrinkage and agglutination. His argument strongly urges that a large outer zone of the tectorial membrane is produced by the cells of the spiral organ (and the cells of Claudius?), which zone he claims remains permanently attached in the adult to the cells producing it.

Held describes and figures for the rabbit fetus these tangled fibrils arising from the lesser epithelial ridge and later attached to the cells of the spiral organ, and calls them 'Haftfasern.' He thinks that a part of his Decknetz and a narrow outermost zone of the membrane is formed from them. In none of his figures from the rabbit do his Haftfasern show an abundance and arrangement similar to that of the membrane. On the contrary, his figures for his fetuses up to near term, show what I consider the outer edge of the tectorial membrane proper to terminate bluntly at the axial side of the series of inner hair cells. He states that his narrow outermost zone (formed from the fibrils in question) is not distinguishable in the older stages and he thinks it a retrogressive structure, for later, when the whole outspanning zone of the membrane is becoming free, he finds only a thin relatively coarse net upon the outer edge (selvage) of the membrane.

Rickenbacher, for the fetal guinea-pig, shows a mass upon the lesser epithelial ridge, after the hair cells have differentiated, considerably greater than I have seen in the pig. He described it as of the nature of his granular, pale staining layer in which fibrils appear, stating that in guinea-pigs of 5.5 cm., the tectorial membrane proper ceases at the immediate axial side of the inner hair cells and that the pale staining mass becomes a fibrous 'Deckschicht' upon and produced by the spiral organ, and that it becomes a process of the tectorial membrane proper (p. 395). In another place he states that it adds a small outer zone to the membrane. It is later detached from the spiral organ, he agreeing that the outspanning zone of the developed tectorial membrane of the guinea-pig is free.

Prentiss charges that I misrepresented Rickenbacher in using his name as one who agreed that "there is no good reason to assume that the cells giving rise to the organ of Corti ever have anything to do with" the development of the tectorial membrane. In again going over Rickenbacher's paper, I find Prentiss' charge a true one, and I cannot conceive of my reason at that time for using his name as I did in the sentence quoted by Prentiss. It is barely possible that his name was used instead of that of another author, Hensen probably, for while only in the passage of his paper incorporated by Prentiss does Rickenbacher state at all definitely that he considers a part of the tectorial membrane proper *developed from* the lesser epithelial ridge, yet in several places one may infer that he does so consider it. In the passage incorporated by Prentiss, the part in question is referred to as follows: "Die schmale Randzone ist eine sekundäre Bildung, welche an dem kleinen Epithelialwulst *abgesondert* wird." (Italics are mine). In my paper, as stated, no attempt was made to enter fully into the processes of development of the membrane. Sections from relatively few early fetuses were examined. The purpose was to learn something of the nature of the membrane already developed. In the few sections I had representing the stages of the differentiation of the spiral organ, the fibrils over the lesser ridge must have been exceptionally sparse, for I considered them as artefact and omitted to show them in the one figure offered dealing with development. Granular masses and filaments are usually seen in the sections adhering upon other parts of the epithelium lining the cochlear duct, especially in its angles, and I described the fibrils I saw as a thin, frayed reticulum, sticking upon the lesser ridge and continuous with the tectorial membrane, composed of coagulum filaments resulting from the action of the fixing fluid upon the endolymph. I considered Rickenbacher's pale staining substance over the spiral organ as artefact, most especially his detailed presentation of it in his figure 15, for in this he showed it as adhering to the young spiral organ by five stout processes, four of which each blended upon and surrounded only the hairs of the inner and outer hair cells. Between these few attaching processes were shown what were evidently shrinkage spaces, though he called them 'intercommunicating spaces in which the endolymph circulates.' He called the processes 'fiber bundles,' which was perhaps true, but the predominant structure of his mass appeared to be granular and I considered it artefact, as it was, especially the arrangement of his fiber bundles. In the present study, I cannot agree for the pig with any of his interpretations of his Deckschicht. I agree with him that the tectorial membrane becomes free from the spiral organ.

Up to pigs of about 16 cm., the greater epithelial ridge grows thicker and wider and the activity with which the membrane is produced by it increases. The outer third of the greater ridge becomes thicker than the axial two-thirds, the position of its nuclei giving the impression that its long cylindrical cells have been forced apexward by growth pressure. Figure 7, from the 3rd half turn of a pig of 14 cm., shows this but to a less extent than may occur at 16 cm. The rapidly growing, outspanning zone of the tectorial membrane coincides with the surface of the greater ridge throughout. Its outer third cups around or clasps the more elevated outer third of the greater ridge, and its rounded edge is curved basalward to terminate at the inner hair cells of the young spiral organ (figs. 7 and 8). The cells comprising the outer margin of the greater ridge are directed outward, diverging toward a direction parallel with the surface of the spiral organ and thus maintaining the position approximately vertical to the basal surface of the enclasping outer edge of the membrane. The bluntly rounded outer edge of the membrane is frequently torn loose in the preparation of the sections. Then it may be straightened outward over the spiral organ, either projecting free from it or often pressed down upon it when distorted. Quite often, when torn free or distorted by pressure, the edge appears shrunken to a flattened, dark staining projection. Even when undisturbed and undistorted, the outer edge may project over the inner hair cell, as in figure 7. Then the fibrils supplied to this edge by the reclining cells of the outermost part of the greater ridge may be traced to curve into and around the edge, contributing to its rounded contour.

The fibrils produced by the lesser ridge and attached to the now thickened outer edge of the tectorial membrane, appear drawn more straight by the growth of the membrane and appear continuous with the 'peripheral condensation' of the apical surface of the outer edge. These fibrils and the apical peripheral condensations are considered above as homologous in that both represent the product of the first activities of the cells, a product less completely formed or organized than the body of the tectorial membrane later produced by the cells of the greater ridge. The fibrils, early formed by the lesser ridge, must contribute but a very small part of Held's Decknetz, for it is hardly possible, considering the physical character of the tectorial membrane and the very evident delicacy of the fibrils, that they can be pushed around and upon the apical surface of the membrane. In figure 8, which represents a section of the 3rd half-turn of the cochlea of a pig of 19.5 cm., is indicated, I think, the process of rupture and disintegration of the few and always loosely associated fibrils produced by the lesser epithelial ridge.

The further increased thickness of the outer edge of the tectorial membrane, added to it from the basal side, has begun to draw into bundles and tear apart the sparse fibrils. From the preparations of stages below and above that represented by figure 8, I think that the cells of the lesser ridge, now the more advanced spiral organ, ceased to produce fibrils in pigs of about 12 to 14 cm., and never actively produced them. Being at the beginning involved with those produced by the greater ridge, the fibrils on the lesser ridge and later spiral organ remain continuous with the outer edge of the tectorial membrane proper but they contribute practically nothing to it. When produced in unusually large amount, they may produce the appearance of the loose plexus attached to the freed outer edge of the membrane observed by Held in the late fetus, or they may produce the "border plexus of Lowenberg" described in late fetuses by others. But, they partially if not entirely disintegrate. There is no evidence of them upon the clean, rounded, outer margin of tectorial membrane of the adult pig or even of the pig at full term: they do not show on the fully developed spiral organ, unless they may possibly contribute something to its lamina reticularis.

In figure 8, the beginning of the cessation of production and the recession of the cells of the greater ridge is well advanced. The attached axial zone of the membrane ceases earliest to grow, of course. The invasion and growth of the mesenchymal tissue to form the vestibular lip of the spiral limbus soon involves the epithelial cells, which never become so high in the region, pocketing them in an inactive condition. Cessation of activity of the cells of the greater ridge proper begins under Huschke's teeth and progresses outward. The activity seems to wane, the last product being less complete than earlier, then the cells begin to recede, their fibrils torn asunder as the space between them and the basal surface of the membrane increases. The receding cells decrease in number. The cells of the outer and thickest part of the greater ridge remain active longest, produce the thickest part of the membrane and its outer edge. With the recession and reduction of the outer part of the ridge, the membrane has attained its adult proportions. The greater ridge grows progressively wider and thicker toward the apical end of the cochlea and remains active longer at the apical end, thus producing the progressively broader and thicker apical end of the membrane. Figure 9, drawn from a section of the 3rd half turn of the cochlea of a pig of 22 cm., suggests the persistent activity of the outermost part of the greater ridge. In it, the final retrogression of the producing cells (*GR*) is represented. This retrogression seems to occur after the cells of the axial two-thirds of the ridge have completed their retrogression and decrease in number to form the cells lining the spiral sulcus. The indentation in the basal surface of the membrane over the disintegrating cells is thought to be artefact, for tracing backward through the stages suggests that very little if any of this region of the membrane is contributed by the outer part of the greater ridge. The process by which the spiral organ assumes its position under the outspanning zone of the membrane is about completed and, in the process, the cells which produced the outer regions of the membrane have been carried axisward from their product. Between the membrane and the organ and disintegrating cells, there is, in some of the sections of this stage, a suggestion of delicate fibrils, some of which seem to be drawn axisward. So, if that portion of the membrane which now lies over the disintegrating cells is contributed to by the cells at all, it is most probably only a few delicate fibrils drawn axisward, parallel against and contributing to the peripheral condensation of the basal surface.

Attention is called to the fact that the spiral organ has increased in size between the stage of 19 cm. (fig. 8) and 22 cm. (fig. 9). Though its growth is not quite completed, it has approached the thickness possessed by the adult in this turn of the cochlea. The growth increase in the thickness of the organ is indicated in table 4 in which averages of the thickness are given in micra. The measurements were taken from the surface of the organ, through the middle of the outer hair cells, to the basilar membrane.

Cochleae from one litter of pigs averaging about 21 cm. showed the differentiation of the spiral organ completed in the 3rd half

TABLE 4

Giving in micra averages of the thickness of the spiral organ (of Corti) as found for the pig in the various stages of development and the regions of the coil of the cochleae specified

SPECIMENS		1ST HALF TURN	3RD HALF TURN	5TH HALF TURN	7TH HALF TURN
Number used	Sizes pig				
2	16 cm.	34.6	30.8	30.8	38.5
4	19.5 cm.	52.4	53.9	60.1	52.4
2	22 cm.	69.3	84.9	61.6	46.2
5	near term	102.0	89.2	71.3	52.0
5	adult	113.1	104.4	85.2	55.4

turn. The cochlea from which figure 9 was made came from a pig of 22 cm. and the two of this stage measured for the results recorded in table 4 were chosen from this lot of pigs. The spiral organ was some thicker in one of the two than in the other. The variations in the thickness of the 7th half turn, shown in table 4, are due largely to the varying distances from the actual basal end of the organ at which the plane of section passed, for at 19 cm., in my specimens, the differentiation of the organ in the basal region is about completed. Examination of the various stages, and the measurements, show that with the beginning of the differentiation of the spiral organ from the lesser ridge, the organ begins to increase in thickness throughout the cochlea, and that, though the increase takes place most rapidly in the stages before full term, it seems to continue after birth. The increase is greatest in the apical end.

The growth increase in the width of the organ could not be accurately measured in the 1st and 3rd half turns till above pigs of 22 cm., because, as shown in figure 9, its differentiation was not complete. It is usually completed throughout in pigs of full term. The varying width of the organ in the adult is given in table 3.

As suggested in the figures, the cells of the greater epithelial ridge finally all sink till they are represented only by the relatively few, broad, fattened cells lining the internal spiral sulcus. The outermost five to eight of the cells of the greater ridge retain a portion of their high cylindrical form and become the inner supporting cells of the spiral organ. As such, they retain to an extent their outwardly reclining direction. In the recession and disintegration of the cells, the decrease in number is such that the cells (nuclei) in the greater epithelial ridge of the apical turns at 15 to 16 cm. are twenty to twenty-five times the number of the cells which line the internal spiral sulcus and comprise the inner fourth (the smaller supporting part) of the mature spiral organ. Held and others before him have shown for other mammals that the retrogression and disintegration of the cells of the greater ridge begins at the axial edge of the ridge and proceeds outward, thus freeing from attachment first the axial border of the outspanning zone of the tectorial membrane; and Prentiss notes that the "inner half of the spiral organ" (inner supporting cells) is derived from the greater ridge.

The inner supporting cells, during their differentiation from the cells of the greater ridge recede slightly. Then they increase in both height and size in the increase in the size of the spiral organ so evident in the apical coils of the adult hog. However, as shown in the figures and as will be noted below, the outer supporting cells (cells of Hensen) increase in height and size considerably more than the inner during the growth of the apical regions of the organ. The cells of Claudius also decrease slightly in height and increase in width between the early fetus and the adult form of the spiral organ. The decrease in height seems to result from loss in their distal ends, for the nuclei are situated earlier in the middle and proximal (or basal) ends of the high columnar cells and later in the distal ends of the low columnar and cubic cells. In the adult, the cells of Claudius appear to increase considerably in height in passing from the apical to the basal end of the cochlear duct. It may be suggested that both the spiral organ and the cells continuous with it, though their differentiation is completed earliest in the basal end, do not undergo so extensive differentiation in the basal as in the apical end; (compare figures 1 to 4). Further, from study of the different stages of development, it seems probable that at least four cells of the lesser ridge take part in forming the boundary of the tunnel of the spiral organ in a given section of it: (1) Each of the pillars of the organ appears to be produced by a separate cell which is entirely used up in the process and its nucleus disappears; (2) the 'foot cells,' one bracing against the inner side of the basal end of each pillar, seem to be derived separately, and though they may aid in nourishing the pillars, they probably have little or nothing to do with their production.

Figures 10 and 11 are given to illustrate respectively the actual and the more usually apparent relation of the basal surface of the growing tectorial membrane to the cells of the greater epithelial ridge producing it. Each of the figures represents a few cells of the outer side of the middle third of the greater ridge, figure 10 from the 5th half turn of a pig of 15 cm. and figure 11 from the 3rd half turn of one of 14 cm. The letter *J*, indicating the line of junction between the membrane and cells, is placed on the axial side of each drawing. Figure 10 shows an appearance seldom found in the sections of embedded material, but the appearance is, I think, the correct one. By close observation of the specimen from which it was made one may note from 3 to 8 fibrils given off from the apical end of each cell. The fibrils pass almost vertically from the surface of the cells and then curve axisward in the part of the membrane previously formed. Each fibril shows a slight, elongated enlargement in its immediate junction with its cell. The number of fibrils observed from each cell probably depends upon the planes in which the cells are split by the section more than upon variation in the sizes of the cells. The cells average about 7 μ in diameter. Held computed for the rabbit from 33 to 38 fibrils per each 100 μ of the surface line of section of the greater ridge. If 5 fibrils be considered as the average per cell, then each 100 μ of surface of the ridge in the pig may involve about 70 fibrils. Taking into consideration the third dimension of the cell, as many as 25 fibrils may be given off by each cell.

That, beginning in the apical surface of the membrane, the fibrils course from the axial side outward and then basalward to their cells of origin is due to the fact that the greater ridge increases greatly in width outwardly while the fibrils are being produced. Later, toward completion of the membrane, as the cells begin to recede along the axial side of the ridge and the ridge begins to decrease in width, the last produced ends of the fibrils are drawn axisward in the basal surface of the membrane. This drawing axisward is done only by the cells of the thicker and more persistent outer part of the greater ridge, the drawing. I think, extending in the basal surface only about as far axisward as Hensen's stripe, which it helps to form as well as helping to form the basal peripheral condensation as seen in the sections. The fibrils thus drawn axisward must form the arrangement on the basal surface of the outer part of the teased out membrane described by me as an "accessory tectorial membrane."

The increase in the number of cells in the greater ridge during its increase in width results, of course, in an increase in the number of fibrils and thus in the width of the membrane as compared with the earlier stages. If the claim made by Prentiss that the tectorial membrane is a honey-comb or chambered structure, each chamber coinciding with and produced by a cell, were true, then in the sections would be found occasionally strips as wide as the cells, walls of the chambers parallel with which the plane of section had passed. Such strips have never been seen. On the contrary, the fibrillar character is one of the most evident possessed by the membrane.

In sections in which the condition similar to that shown in figure 10 could be seen, the region of junction (J) appeared lighter than the earlier formed part of the membrane. This is interpreted as indicating that the interfibrillar matrix here has not, as yet, been completely formed. Figure 11 represents the condition, some degree of which is the usual appearance in all sections of dehydrated cochleae while the membrane is being formed. It is interpreted as the result of the action of the reagents, used in the preparation for sectioning, upon the last and not yet perfectly formed part of the membrane. The matrix in this region must be in a stage more readily shrunken by dehydration and clearing than in the earlier formed part of the membrane. The fibrils appear agglutinated into irregular bundles with spaces between them more or less free. In the area drawn the bundles were formed for the most part, one on the end of each cell, similar to the way cilia often appear in brushes in sections of the uterine tube and the ducts of the testis, for example. When shrinkage and agglutination are less evident than in figure 11, the bundles are smaller and may be formed indifferently upon and between the ends of the cells. When more shrinkage has occurred the bundles may be larger and the shrinkage spaces may extend over several cells. The spaces are similar to those Rickenbacher pictured and considered as designed for the circulation of endolymph. Figures 10 and 11 are not camera drawings.

The *attachment and functional position* of the tectorial membrane are interrelated. The outspanning zone, after it is produced, becomes entirely free, first from its slight attachment to the young spiral organ (lesser epithelial ridge) and later from its parent cells, and the process by which it becomes free is the chief of the processes by which it later attains its functional position over the spiral organ. Held ('09) quite fully reviewed the ideas advanced by the different authors as to how the auditory hair cells, developed in the lesser ridge at the outer edge of the growing membrane, acquire their much more axial position well under the membrane, and I cited most of them in my former paper. I think all the processes possible have been suggested. When the younger stages are compared with the stages after birth (compare figures 7 and 8 with figure 2) it is seen that the spiral organ may become so shifted in its relative position that its hair cells come to stand under the middle of the basal surface of the outspanning zone of the membrane, and that the outer edge of the membrane may project in the 3rd half turn (and no doubt more in the 1st) well beyond the organ and even over the first 10 or 12 of the cells of Claudius. Under the narrow basal end of the membrane (fig. 4), the shifting of position is barely sufficient to bring the outer edge over the outer hair cells of the organ. In this region the greater epithelial ridge completes the membrane earlier, is active during a shorter period, and increases in width during production much less than in the apical turns. It may be noted further that in the more apical turns the outer supporting cells increase in height so much more than the inner that the apical surface of the spiral organ becomes markedly inclined axisward.

The ideas advanced as to how the spiral organ attains its relative position under the membrane include: (1) that the organ becomes shifted axisward bodily along the basilar membrane; (2) that growth in width and thickness of the vestibular lip of the spiral limbus serves to tip and project the membrane, attached upon it, over the spiral organ; (3) that the increase in the size and height of the outer supporting cells (cells of Hensen and Deiters) presses the hair cells axisward, causes the apical ends of the pillars to lean axisward and actually slightly displaces axisward the feet of the pillars; (4) that the membrane is produced in its functioning position with reference to the organ instead of there occurring a shifting of position of either the organ or the membrane.

The latter idea, that the tectorial membrane is produced in situ without changes in its position relative to the hair cells, was naturally one of the first to be advanced. Early discarded, it has been revived by Held and adopted by Prentiss. It requires, of necessity, that in the apical turns, the thicker, outer two-thirds of the outspanning zone be produced by the spiral organ, largely after its elements have been differentiated, and by the cells of Claudius (compare figure 7 with figure 2). A stage of development has never yet been described and, I think, never been seen, certainly not in the pig, in which this thicker (and, in the apical turns, by far the greater) part of the membrane was being produced by the cells of the differentiating spiral organ and the cells of Claudius. In the pig, and in the published figures from other mammals, the few sparse, loosely arranged and unsupported fibrils described as produced by the cells of the lesser ridge, attain their maximum amount long before the differentiation of the elements of the spiral organ is completed. They are produced, I think, most rapidly in the pig before the differentiation is well under way. The cells of the lesser ridge have never been seen in a relation to the growing membrane similar to that of the cells of the greater ridge seen in all specimens, and further, what is most evidently to be the whole outspanning zone of the membrane is found during its production, in all trustworthy preparations of the pig, overlying the cells of the greater ridge only and associated with them only. The idea is very simple but I am convinced the actual anatomy in development does not support it. From my study of the specimens I, as yet, find no evidence that the few fibrils seen coming from the lesser ridge and continuous with the outer edge of the membrane proper can contribute appreciably, if at all, to the bulk of the membrane. I think they disintegrate for the most part at least, leaving the outer edge of the functioning membrane clean and bluntly rounded, its fibrils curving from the apical surface around the edge and axisward in the basal surface. Both Rickenbacher's and Held's figures, from other animals, show what I consider the outer edge of the later tectorial membrane extending only to the inner hair cells.

Comparison of the different stages suggests that each of the other three ideas is tenable in part, two of them especially; that the relative position of the organ to the basal surface of the membrane does become shifted and that three factors may enter:

(1) The growth increase in thickness of the vestibular lip of the spiral limbus can have nothing to do with inducing the membrane to span the spiral organ. Averages obtained from measurements in several cochleae of each of six stages from 13 cm. to the adult show that in all the turns of the cochlea, the lip acquires its adult thickness in the fetus of 14 to 15 cm. At this stage the membrane proper is still being produced in all the turns of the cochlea and does not anywhere project over the spiral organ. The thickness of the lip in the different half turns in the pig of 14 cm. and the older stages, including the adult, were found to be strikingly similar. Further, the vestibular lip attains less thickness throughout in the apical turn than in the basal, while the membrane projects over and beyond the organ more in the apical turns. So it is hardly probable that the membrane is tipped outward by increase in thickness of the vestibular lip of the spiral limbus. The width of the vestibular lip, while difficult to measure definitely, likewise seems to increase very little between 14 cm. and the adult. The small

increase in width is mostly attained in that part of the lip upon which the axial zone of the tectorial membrane is attached, that is, from the insertion of the vestibular (Reissner's) membrane to the edge of Huschke's teeth, and the edge of Huschke's teeth projects outward farther in the full term fetus and adult than in the earlier stages (compare figures 2 to 7). The average widths of this part of the lip, which is most of it, are given in table 5. The greater variations in the averages for the width at the 1st half turn are due to the varying distances from the tip end of the lip at which the knife passed, for the lip narrows suddenly in terminating in the hammulus. The slight increase in width, shown in the table, between 13 cm. and 22 cm. can have little to do with other than the growth of the attached axial zone of the membrane. At 13 and 14 cm. the part of the lip in the 1st half turn is not sufficiently outlined to measure. Most of the increase seems to occur after 22 cm., that is, between this and the fetus at term and the adult, when the membrane is becoming and has become detached from its parent cells and from the spiral organ. This latter increase in the width of the lip may contribute a slight projection of the tectorial membrane outward and over the spiral organ. The width of this part of the lip is about the same as the width of the attached axial zone of the membrane.

TABLE 5

Giving in micra averages of the width of the vestibular lip of the spiral limbus from the insertion of the vestibular membrane to the edge of Huschke's teeth in the different sizes of the pig and the different turns of the cochlea specified

SPECIMENS		1ST HALF TURN	3RD HALF TURN	5TH HALF TURN	7TH HALF TURN
Number used	Length				
3	13 cm.		125.7	125.5	151.0
4	14 cm.		159.6	152.0	159.6
4	15 cm.	152.0	190.0	171.0	186.2
2	16 cm.	68.4	174.8	182.4	155.8
3	19.5 cm.	133.0	186.2	182.4	184.3
2	22 cm.	161.7	209.0	197.6	186.2
6	near term	179.4	216.6	214.5	202.2
5	adult	193.8	206.7	206.7	190.0

(2) As seen in the drawings, the spiral organ grows in thickness between the time the tectorial membrane begins to span over it and the adult stage. The greatest increase in thickness occurs in its outer side by the increase in the length of the outer sustentacular cells, and the apical ends of these curve axisward. As a result the apical surface of the organ is made to incline axisward. The outer pillar of the organ also increases in length more than the inner pillar, and as a result of this, and perhaps of the increase in the length of the outer supporting cells also, the apical ends of the two pillars are forced axisward. At their differentiation, the apical ends of the pillars incline strongly outward (see fig. 8, 19 cm.) in conformity with the pressure of the cells of the outer part of the greater epithelial ridge. It seems evident, therefore, that the apical surface of the organ is forced axisward during growth and therefore under the tectorial membrane to a slight extent. The normal spaces between the elements of the spiral organ, including the large Nuel's space, no doubt result in part from this movement of the organ axisward. Nuel's space, however, is present in considerable size before the upgrowth of the outer supporting cells has started (compare figures 8 and 2). This space increases in passing from the basal to the apical end. Any movement of the surface possibly produced in this way is, however, not enough to account for the change in relative position of the organ evident in the apical turns. In the basal end, the great increase in the height of the outer supporting cells does not occur, thus the apical surface of the organ is not inclined axisward, though, the pillars do not lean outward as might be expected. The change in the relative position of the organ with reference to the basal surface of the tectorial membrane is less in the basal end and progressively increases in passing toward the apical end.

(3) To accomplish the very marked shift in the position of the spiral organ with reference to the basal surface of the tectorial membrane, especially in the apical turns, some process is necessary by which the entire organ is moved axisward. During differentiation of its elements, the spiral organ is situated

along the outer edge of the membrane and is even attached to this edge by the sparse fibrils formed by its cells before their differentiation is completed (fig. 7). In the adult the hair cells in the apical turns come to stand under the middle of the wide outspanning zone (fig. 2).

Pressure displacement of tissue in the direction of the least resistance is common in organogenesis and, in the adult, such displacement is a common observation of the surgeon. Comparison of the stages of the pig in the different turns of the cochlea shows that the feet of the pillars separate during the growth of the organ. The separation is greatest toward the apical end. Hensen ('71 and '73, cited from Held) found by measurement in the ox that the feet of both pillars are moved axisward. In the apical turn he found that the foot of the outer pillar shifted about 37 μ and that of the inner pillar about 95 μ, thus not only indicating actual movement but also accounting for the separation of the feet during the enlargement of the organ. I do not know between what stages of ox fetuses the measurements were made. If two elements of the spiral organ move axisward at all, it is possible that all the elements may move. If the elements move at all, it is possible that they may move sufficiently to account for the change in the relative position of the organ. During the rapid increase in the width of the greater epithelial ridge, the differentiating spiral organ is moved outward.

The cells of the greater ridge, when it is widest (in pigs from 14 to 16 cm.), are about twenty-five times greater in number than the cells, derived from the ridge, which later line the internal spiral sulcus. The cells lining the sulcus in the adult are broader than the cells of the greater ridge, but they average certainly not more than three times as broad. As shown above, at from 13 to 16 cm., the outer third of the greater ridge is thickened into a rounded elevation, its cells and nuclei being displaced apexward and its outermost cells being forced in the outward direction (figs. 7 and 8), indicating considerable growth pressure. In the later recession and disintegration of the cells of the greater ridge, as the production of the tectorial membrane is completed, the pressure must not only be relieved, but, from the marked decrease in number of cells, there may result an almost negative pressure.

Measurements show that the space occupied by the width of the greater epithelial ridge increases throughout the coils of the cochlea up to pigs of 15 to 16 cm. (when the ridge is widest) and thereafter it begins to decrease very perceptibly. The measurements were taken from the membrana propria of the epithelium of the greater ridge, at its most axial extension under Huschke's teeth (*S*, figs. 1 and 7), to the apical end of the inner hair cell of the spiral organ. The averages of the measurements are recorded in table 6. As in the other tables, some of the variations in width of the greater ridge, and internal spiral sulcus, evident in the 1st and 7th half turns are due to the varying distances from the apical and basal ends of the cochlear duct at which the knife passed. In the specimens from pigs of 9 to 11.4 cm., the 1st half turn was not completed, and in those from 13 to 14 cm., the differentiation of the vestibular lip of the spiral limbus in this turn was not sufficient for the measurement. In the 3rd half turn of the 9 cm. pig (see fig. 6) this differentiation had not taken place, and thus this

TABLE 6

Giving in micra averages of the width of the developing and developed internal spiral sulcus, measured from the membrana propria of the epithelium under Huschke's teeth to the apical ends of the inner hair cells of the spiral organ, in the different pigs and the different regions of the cochlea specified

SPECIMENS		1ST HALF TURN	3RD HALF TURN	5TH HALF TURN	7TH HALF TURN
Number used	Length				
3	9 cm.		231.0	238.7	192.5
3	11.4 cm.		284.3	292.6	223.3
3	13 cm.		277.2	292.6	227.2
3	14 cm.		300.3	269.5	231.0
4	15 cm.	254.0	330.0	297.3	274.8
2	16 cm.	261.8	323.4	261.8	177.1
3	19.5 cm.	241.8	289.5	257.2	175.6
2	22 cm.	231.0	250.3	216.4	161.8
6	near term	193.9	231.2	234.1	193.9
5	adult	188.9	232.5	219.6	130.9

measurement is only approximate. Individual pigs of a given length vary in the degree of development of the cochlea, especially if from different litters.

It may be seen from table 6 that between pig fetuses of 9 and 15 cm. the width of the greater epithelial ridge increases appreciably, and between 15 cm. and the adult the width of the space occupied by it decreases. The increase and the decrease is evidently greatest in the apical part of the cochlea. The decrease in the 1st and 3rd half turns may be as much as one-third of the width of the greater ridge when at its maximum size and activity. During the development of the spiral organ from the lesser epithelial ridge, the apical ends of the inner hair cells are in line along the outer edge of the growing tectorial membrane. In the 3rd (and no doubt the 1st) half turn of the adult organ, these ends of the hair cells are situated along about the middle of the width of the outspanning zone of the membrane (fig. 2). In other words, it is suggested that in the apical coil of the cochlea, after the tectorial membrane is about completely produced and while the spiral organ is enlarging, the inner hair cells, and therefore the organ, may be moved axisward a distance of about half the maximum width of the greater epithelial ridge, the maximum width of the ridge representing approximately the width of the outspanning zone of the membrane produced upon it.

It is suggested that a movement axisward of the organ of about one-third the width of the outspanning zone may be induced by the pressure of the growing cells of Claudius and the enlarging supporting cells on the outer side of the organ, and be allowed by the retrogression and decrease in number of the cells of the greater ridge on its axial side. The remaining one-sixth of the distance estimated for the apical coil may be accomplished by the other but less effective processes mentioned, namely, the inclination axisward of the apical surface of the organ. Table 6 shows that the movement is not so much in the basal part of the cochlea and figures 3 and 4, the 5th and 7th half turn of the adult, show that the distance of the inner hair cell from the outer edge of the membrane is less in the basal coils than in the apical turn. At the basal end, the greater ridge remains narrower and produces the narrow end of the membrane. Where the greater ridge is widest, there the membrane is produced widest, the reduction in the cells of the ridge is greatest, the enlargement of the outer supporting cells is greatest, and there, as a result, the change axisward of the spiral organ is greatest.

Prentiss states that measurement "shows no important change in the position of the spiral organ from the 13 cm. to the 18.5 cm. stage, nor later in the newborn" pig. He allows the inference that he measured "the distance between the inner angle of the cochlea and pillar cells," but gives no records of measurements. His averages for the 13 and 18.5 cm. stages and those for the newborn pig would have been interesting for comparison with like measurements that could be made in the specimens used here. On page 434 he describes the greater ridge as increasing in width by growth and multiplication of its cells, "carrying the spiral organ outwards," while he denies in other passages the possibility of the spiral organ being carried axisward.

With the completion of the retrogression and disintegration of the cells of the greater ridge and the simultaneous movement axisward of both the entire spiral organ and its apical surface, the thick, outspanning zone of the tectorial membrane, of necessity, becomes free. The few loosely arranged fibrils, produced by the lesser ridge before its completed differentiation into the spiral organ, may persist and remain attached to the outer edge of the membrane till torn asunder in the freeing process. There is no evidence of them on the membrane of the adult. In the fetus at term, when the process of freeing is being completed, it is possible that remnants of them may at times adhere as a delicate plexus to the outer edge of the membrane.

It is possible that the outer margin of the tectorial membrane, which, during its production, cups around the outer part of the greater ridge, may straighten outward slightly upon being freed. If so, such behavior would contribute slightly to the projection of the membrane beyond the spiral organ.

The thin axial zone remains attached upon the vestibular lip of the spiral limbus. The cells producing this are never thick, do not undergo the growth disturbances undergone by the greater ridge proper, and the fibrous mesenchymal tissue added about them in the formation of the lip aids them in retaining the attachment. This, I am convinced, is, in the pig and probably all mammals, the only attachment of the tectorial membrane after acquiring its functioning form.

The freeing of the outer zone may not be an absolute necessity for the mediation of auditory impulses. In the birds the sensory cells, corresponding to the hair cells of the mammal, are dispersed in a simple epithelial ridge producing both them and the tectorial membrane, and the ridge not receding and disintegrating, the membrane remains attached to its parent cells. In the mammal, the otolith membranes of the maculae are homologous to the tectorial membrane, though simpler, and these remain attached in part to their parent epithelium, situated in which are the special sensory cells. Experiments with the model I have tried to construct, imitating the tectorial membrane and its environment, suggest that, were the outspanning zone attached, it could be disturbed by vibratory disturbances in the endolymph, though not so readily nor so definitely as when the zone is free. However, in the actual anatomy of the mammalian cochlea it is evident that this zone is free. Held ('09) cites Preyer for the observation that auditory reflexes do not begin in the guinea-pig till one-half hour after birth, and both Held and Rickenbacher found that the outspanning zone of the membrane is freed at about the time of birth. More suggestive are the observations of Kreidl and Yamase ('07) upon rats. As is known, the young of these rodents, unlike the guinea-pig, are born in a comparatively fetal stage of development. They found that auditory reflexes do not begin in them till 12 to 14 days after birth. Held found in rabbits, which, like the rat, are born in a fetal condition, that the outer zone of the tectorial membrane is not free at 6 days after birth, though it is entirely free in the adult stage. He does not describe cochleae of rabbits between 6 days after birth and his stages in which the zone is free.

SUMMARY

1. The bony labyrinth of the adult pig, as well as that of the pig fetus, is not fused with nor enveloped by the petrous part of the temporal bone and thus may be readily removed.

2. A fixing fluid which also slowly but sufficiently decalcifies is best used for normal appearances of the cochlear structures, and, especially with cochleae of adult pigs, it is necessary to make a small hole in the bony labyrinth to relieve pressure of gas formed within during decalcification.

3. Measured within the outer wall of the bony part of the coil, the diameter of the basal coil of the cochlea of the adult ox is 8.4 mm.; that of the adult pig, 5.8 mm.; and that of man, 6.7 mm. The height of the cochlea, from the apical side of the scala vestibuli in the apical turn to the basal side of the scala tympani in the basal turn, was found to be, for the adult ox, 6.7 mm.; for the adult pig, 4.4 mm., and for the human, 4.9 mm. The human cochlea seems to be slightly more flat than those of the ox and pig. The cochlea of the pig at term, exclusive of the outer bony wall, is slightly less in size than that of the adult pig. The slight difference is apparently due to an increase in the size of the two scalae in the adult.

4. The length of the tectorial membrane of the adult pig is estimated from measurements to be about 26 mm. or less than 1 mm. longer than in the fetus at term.

5. The attached, axial zone of the tectorial membrane of the adult pig is of practically the same width throughout the entire length of the membrane.

6. As to the proportions of the outspanning zone of the tectorial membrane of the adult, indicating its adaptedness to serve as the chief vibratory structure of the auditory apparatus: (a) it is widest and thickest at its apical end, tapering gradually and evenly to its basal end, which is its narrowest part; (b) the width of the apical end of the outspanning zone appears from averages of measurements to be 6.8 times its width at the basal end; (c) in thickness, the apical end of the outspanning zone averages in sections of it 3 times its thickness at the 7th half

turn of the coil; (d) in volume, a given short length of the apical end of the outspanning zone may be more than 41.7 times the volume of the same length of the basal end of the zone. Between the basal end and the 5th half turn, the longest interval between measurements in section, the volume of the outspanning zone may increase 90.7 per cent; between the 5th and 3rd half turns, the increase may be 57.4 per cent, and between the 3rd and the 1st half turns, it may be 29.8 per cent. These variations in the proportions are urged in support of the suggestion that the tectorial membrane is far more adapted to serve as the vibratory structure than is the basilar membrane.

7. In the adult pig, the spiral organ (of Corti) increases appreciably in both thickness and width in passing from the basal to the apical end of the cochlea.

8. That the membranous spiral lamina (basilar membrane) may be thrown into vibration by certain strong stimuli is not denied, and that the chief load carried by it, namely, the spiral organ, increases in passing from the basal to the apical end of the cochlea is considered as suggestive of its possible vibratory behavoir. The superior advantages of the tectorial membrane are enumerated and some of its possible activities compared.

9. Pig fetuses of a given length vary very much in the stages of development of the cochlea, especially if from different litters. For a given stage of development, it seems that fetuses obtained in Louisiana average smaller than fetuses obtained in California.

10. The cells of the lesser epithelial ridge, which differentiate into the elements of the spiral organ, at an early stage produce a delicate film of loosely arranged, imperfectly embedded fibrils. These have been erroneously considered by some as increasing to form an outer zone of the tectorial membrane; by others as forming a permanent attachment of the membrane to the spiral organ. It is urged that the cells of the lesser ridge, at first grading from the outer edge of the greater ridge, never actively engage in the production of fibrils, and, as they differentiate into the elements of the spiral organ, they cease the production altogether. They contribute little, if anything, to the formation of

the adult tectorial membrane, though their few fibers may remain attached to its outer edge till torn asunder in the later processes. The membrane is produced by the greater ridge.

11. With the differentiation of the spiral organ from the lesser epithelial ridge, the organ begins to increase in thickness and, though most of this increase occurs in the stages before full term, some of it seems to occur after birth. Growth changes of the organ occur least in the basal end of the cochlea. It is suggested that at least four cells of the lesser ridge take part in a given section in forming the elements comprising the walls of the spiral tunnel.

12. The outermost part of the greater epithelial ridge becomes thicker by growth pressure than the remainder, is active for a longer period, produces the thicker part and outer edge of the tectorial membrane, and its outermost cells, in the process of recession and disintegration of the ridge, seem to differentiate into the inner supporting cells of the spiral organ.

13. In the production of the tectorial membrane, each cell of the greater epithelial ridge may contribute an average of 25 fibrils to the membrane. Each fibril seems to show a slightly elongated enlargement at its junction with its cell. In the region of the immediate surface of the ridge, that of the product of the most recent activity of the cells, the interfibrillar matrix does not appear as abundant, or so completely produced, as in the older body of the membrane. This less completely formed part of the membrane shows shrinkage effects of the reagents in all sections of the cochlea.

14. With the growth in width of the greater epithelial ridge in the early stages, the differentiating spiral organ (lesser ridge) situated along the outer edge of the growing tectorial membrane, is carried outward. The developed spiral organ acquires its position well under the basal surface of the tectorial membrane almost entirely by being carried axisward during the completion of the membrane. As the cells of the greater ridge recede from the membrane they disintegrate to about one-twenty-fifth of their greatest number, thus more than relieving all growth pressure on the axial side of the spiral organ. During this proc-

ess, the outer supporting cells of the spiral organ increase in size and height, producing growth pressure on the outer side of the membrane and producing an inclination axisward of the apical surface of the organ. In the apical turn, where these changes are greatest, the hair cells of the organ may be carried axisward a distance nearly half the width of the membrane. The upgrowth of the outer supporting cells also forces axisward the apical ends of the elements of the spiral organ and in this way contributes a small part to the shift in the relative position of the hair cells. A slight increase in width of the vestibular lip of the spiral limbus may contribute a still smaller part by extending the membrane outward.

15. The outspanning zone of the tectorial membrane is, and of necessity becomes, free with the completion of the recession and disintegration of the cells which produce it, and by the movement axisward under it of the spiral organ. Such of the few fibrils produced earlier by the lesser ridge as may persist are of necessity torn away in the changes in position and all of them probably disintegrate.

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PLATES

REFERENCE LETTERS

AF, lamina of peripheral auditory nerve fibers

AAZ, attached axial zone of tectorial membrane

BM, basilar membrane

CC, cells of Claudius

DC, supporting cells of Deiters

E, endothelium lining scala tympani

ES, epithelioidal syncytium

F, auditory nerve fibers to outer hair cells

GR, greater epithelial ridge or thickening

HC, outer supporting cells (of Hensen)

HS, Hensen's stripe

HT, Huschke's (auditory) teeth

ISC, inner supporting cells of spiral organ

ISS, internal spiral sulcus

IAC, inner auditory hair cells

J, region of junction between fibrils and producing cells

L, lighter outer margin of young greater ridge

LF, fibrils produced by cells of lesser epithelial ridge

LM, liquefying mesenchymal tissue

LR, lesser epithelial ridge or thickening

NS, Nuel's space

OZ, outspanning zone

PC, peripheral condensation of incomplete structure

SG, spiral ganglion

SL, spiral ligament

SP, spiral prominence, stria vascularis

ST, scala tympani

SV, scala vestibuli

TM, tectorial membrane

VL, vestibular lip of spiral limbus

VM, vestibular (Reissner's) membrane

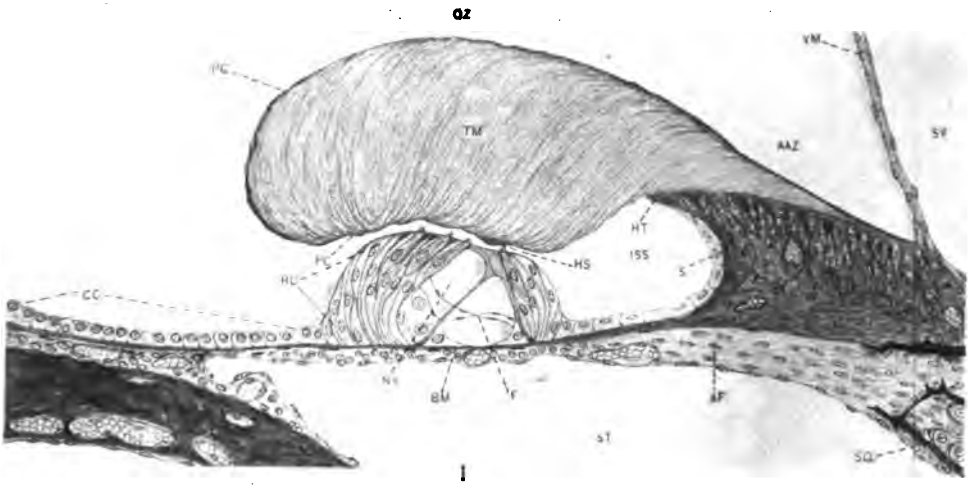
PLATE 1

EXPLANATION OF FIGURES

Figures 1 to 9 are reproduced to scale

1 Section across the 1st half turn of the spiral organ and its tectorial membrane, cochlea of adult hog.

2 Section across 3rd half turn of spiral organ of adult hog; same cochlea as figure 1.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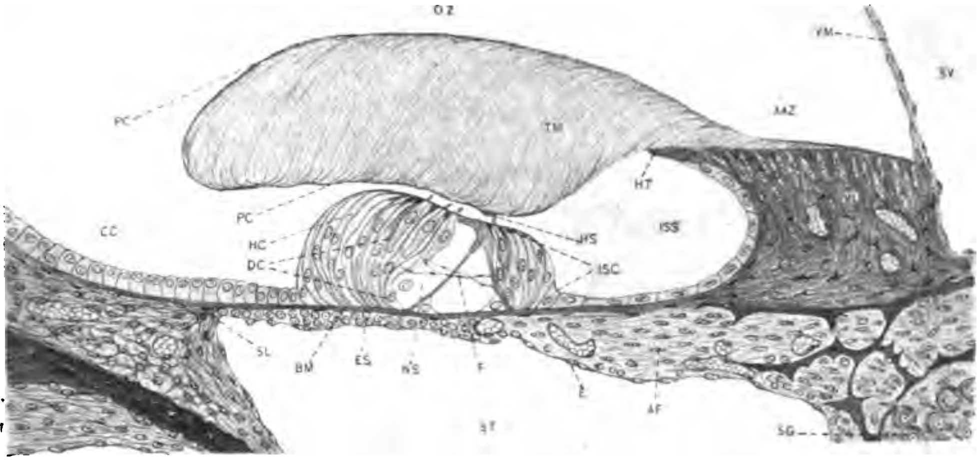
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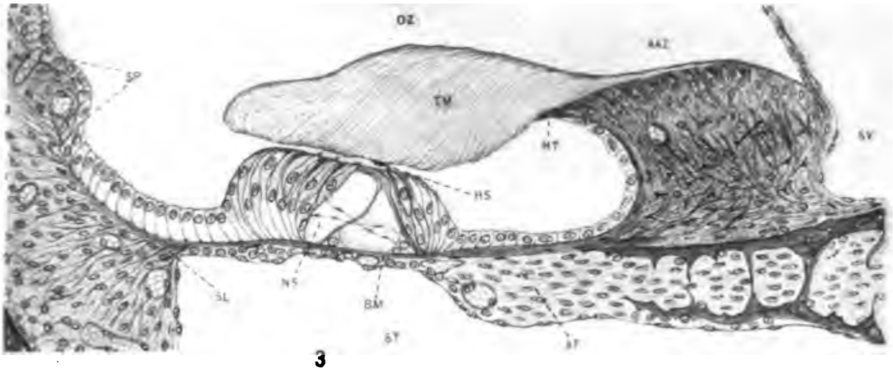
PLATE 2

EXPLANATION OF FIGURES

3 Section across 5th half turn of spiral organ of adult hog; same cochlea as figures 1 and 2.

4 Section across 7th half turn of spiral organ of adult hog; same cochlea as figures 1 and 2, and 3.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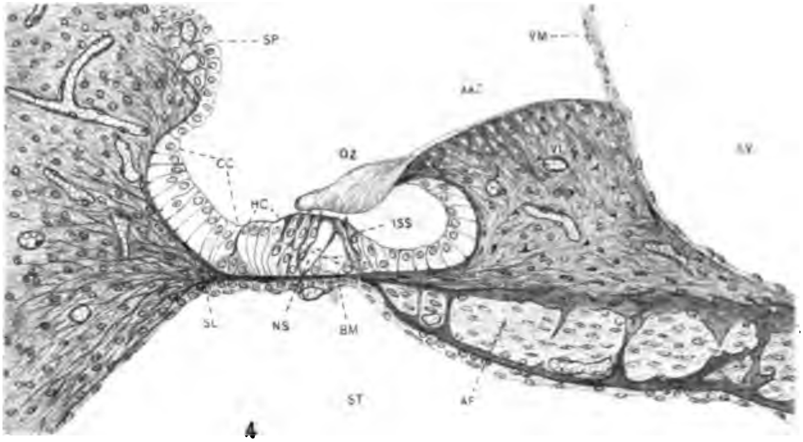
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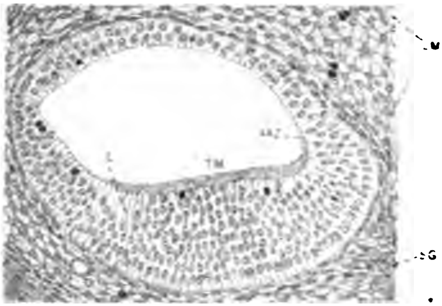
PLATE 3

EXPLANATION OF FIGURES

5 Section of 3rd half turn of cochlear duct of pig of 5.5 cm., showing thickening of epithelium of axio-basal side and beginning of tectorial membrane.

6 Section of 3rd half turn of cochlear duct of pig of 9 cm., showing lesser epithelial ridge and the fibrils produced by it, and advancement in production of the tectorial membrane.

7 Section of 3rd half turn of developing tectorial membrane and differentiating spiral organ of pig of 14 cm.



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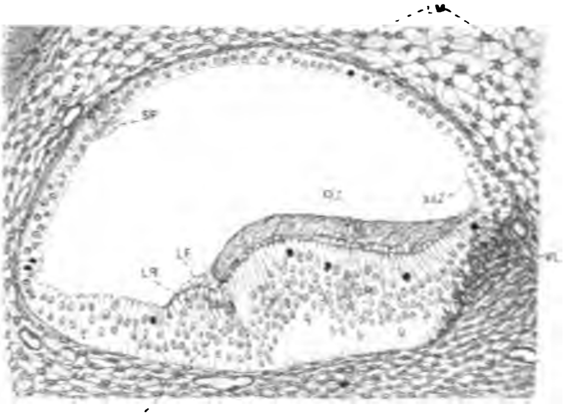

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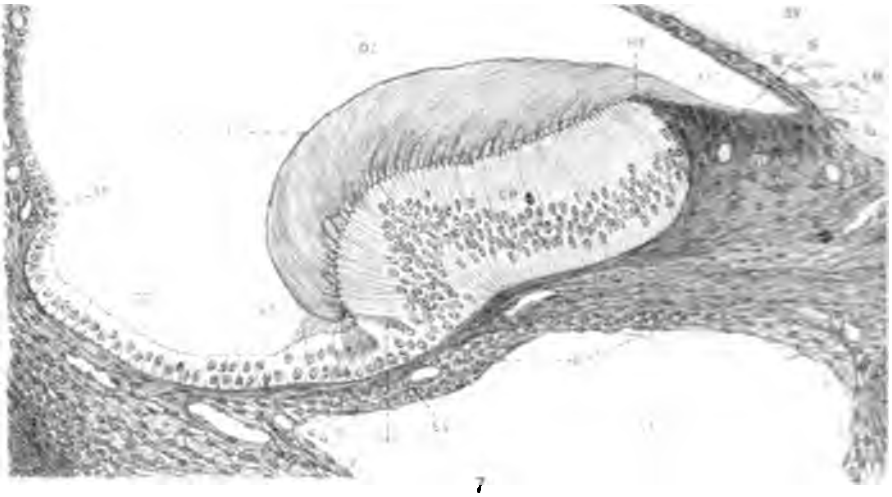

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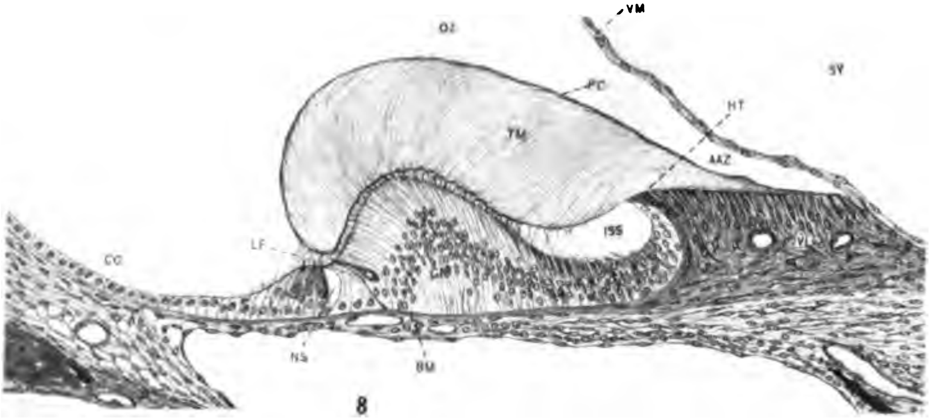
PLATE 4

EXPLANATION OF FIGURES

8 Section across 3rd half turn of developing tectorial membrane and differentiating spiral organ of pig of 19.5 cm. The recession of the cells of the axial side of the greater epithelial ridge is well under way.

9 Section across 3rd half turn of spiral organ and its tectorial membrane of pig of 22 cm. The recession and disintegration of the cells of the outer part of greater epithelial ridge is nearing its completion, leaving the inner supporting cells of the spiral organ.



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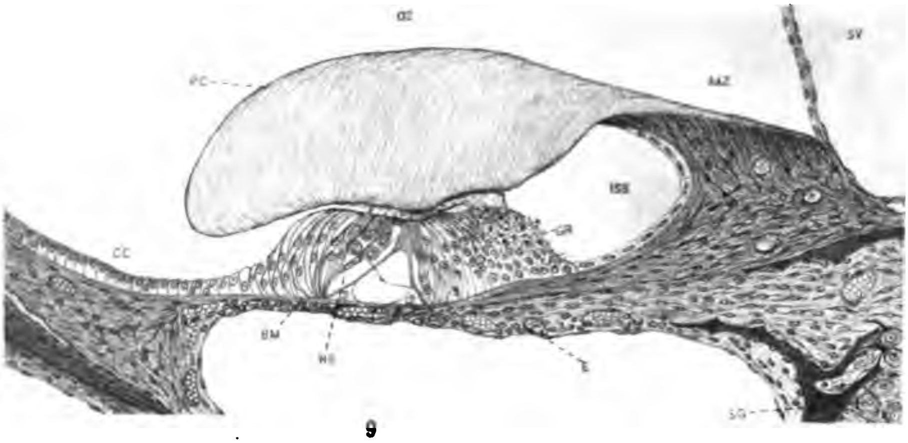

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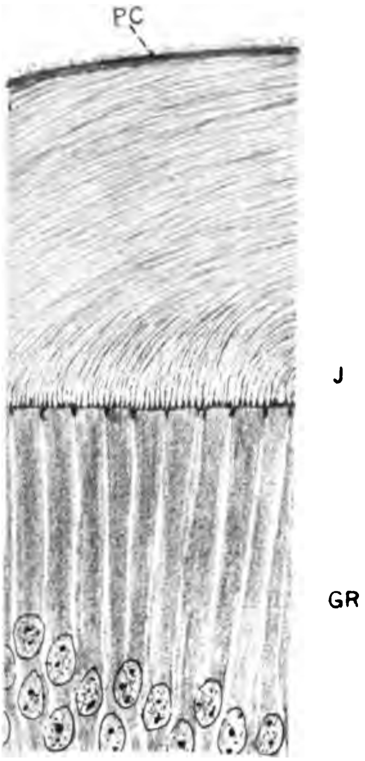
PLATE 5

EXPLANATION OF FIGURES

10 Drawing from the outer part of the middle third of the greater epithelial ridge in the 5th half turn of the cochlea of a pig of 15 cm., showing, at *J*. detail of the relation of the cells of the ridge to the fibrils and tectorial membrane they produce.

11 Drawing from the outer part of the middle third of the greater epithelial ridge in the 3rd half turn of the cochlea of a pig of 14 cm., showing, at *J*, a usual appearance in sections of the relation shown in figure 10, interpreted as due to shrinkage produced by the reagents used in preparing material for sectioning.



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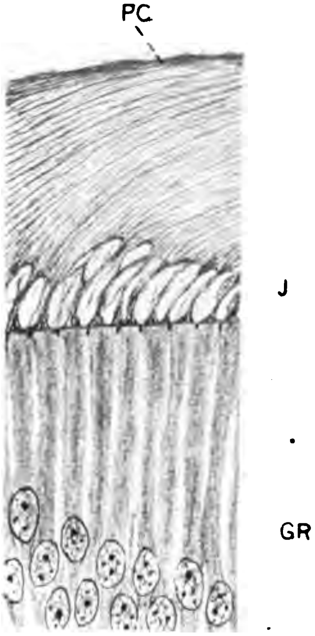

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SOME CHARACTERISTICS OF THE EXTERNAL EAR OF AMERICAN WHITES, AMERICAN INDIANS, AMERICAN NEGROES, ALASKAN ESQUIMOS, AND FILIPINOS

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EIGHTEEN FIGURES (THREE PLATES)

The study of the external ear of man was begun by me in 1905, although I had been making casual observations even before this. While in the Philippines from 1907 to 1910 I segregated many forms of ears, grouping them under three main heads which I called Primitive, Australoid and Iberian for various reasons then set forth (1). Other considerations prevailed and I changed the names from Primitive to Hypo-onto-morph, from Australoid to Meso-onto-morph, and from Iberian to Hyper-onto-morph (2).

The present study is a continuation of those made previously and is more detailed and specific than former studies. It corroborates them in general and in particular, and adds racial distinctions to type differences.

MATERIALS

Morgue subjects

86 ears of New Orleans whites
200 ears of New Orleans negroes
94 ears of Manila Filipinos

Living subjects

103 ears of New Orleans students (white)
94 ears of New Orleans negroes
182 ears of American 'old whites' (three or more generations in America)
222 ears of Washington, D. C., negroes
73 ears of American Indians
171 ears of Alaskan Eskimos
68 ears of fetuses, newborn, and young infants (dead)

This paper is divided into two parts: "Ears of the morgue subjects," and "Ears of the living subjects."

EARS OF THE MORGUE SUBJECTS

The ears of the morgue subjects were measured in 1914 after having been preserved in formalin for variable periods of time from a few weeks to several years.

Each ear was measured as prescribed by Schwalbe, Ranke, Martin and others (13, 15, 16). Seven measurements of each ear were made, the total length, total breadth, cartilage length, ear base, Schwalbe's true ear length (15), the concha length and concha breadth. The concha breadth and length are measurements devised by me to determine the concha index. The concha length is measured from the point where the inferior crus of the concha emerges from the ascending helix, to the inferior border of the intertragic incisure. The concha breadth is measured from the supra-tragic incisure to the point at the greatest distance from this on the inside of the concha opposite.

Helix. Measurements and indices

The average total length and breadth of the ear in millimeters follows:

TABLE 1

Total length of the ear, average in millimeters

NO. OF EARS	RACE; SEX	RIGHT EAR	LEFT EAR	BOTH EARS
67.......	White men	64.95	63.20	64.18
120.......	Negro men	58.81	58.33	58.58
31.......	Negro women	57.67	59.31	58.32
80.......	Filipino men	59.69	58.43	58.80
14.......	Filipino women	57.86	57.00	57.43
19.......	White men	65.20		
41.......	Negro men	59.30		
8.......	Negro women	57.90		

TABLE 2

Total breadth, average, in millimeters

NO. OF EARS	RACE; SEX	RIGHT EAR	LEFT EAR	BOTH EARS
67.......	White men	37.65	36.85	37.19
120.......	Negro men	37.78	37.05	37.43
31.......	Negro women	35.61	35.69	35.63
80.......	Filipino men	33.71	33.43	33.57
14.......	Filipino women	33.30	32.57	32.94
19.......	White men	38.60		
41.......	Negro men	37.40		
8.......	Negro women	37.10		

Physiognomic index of Topinard (16) is the breadth divided by the length:

TABLE 3

Physiognomic index

67 White men...	58.0
120 Negro men...	64.0
27 Negro men...	60.8
80 Filipino men...	56.8
14 Filipino women...	57.5

According to Martin (13) the lowest index of any race so far measured is that of the Aino, 52.8, and the highest is that of the Mawamba pigmies, 66.2. Europeans, as a rule, have a low index, below 60.0, although Alsatians (Schwalbe) have an index of 60.5 (15) and the negroes as a rule have a high index, above 60.0, although the Hottentots have an index of 58.8 [Karutz (12)]. The index of the new born is high, 73.7 for males and 73.1 for females, and it sinks to 58.7 at 70 years of age [Daffner (6)].

Modulus: The ear modulus is obtained by adding the total length of the ear to the total breadth and dividing by two. This gives the ear size in a factor of convenient form. The average module of 67 ears of white men is 50.69, of 120 negro men is 48.0 and of 27 negro women is 46.86. The module for 80 Filipino men is 46.19, for 14 Flipino women 45.19.

Résumé of the total ear dimensions: The ears of the white men are longer than those of the negro men and of about the same breadth. The ears of the negro women are about the same length as those of the negro men but not so broad. The ears of the white men are long and narrow, the ears of the negro men are relatively short and broad, the ears of the negro women are relatively short and narrow and the ears of the Filipinos are short and narrow, relatively narrower than any of the others. The ears of the white men are large, the ears of the negro men and women are small, those of the negro women smaller than those of the negro men, and the ears of the Filipinos are smaller than any of the others, the ears of the Filipino women are the smallest of all.

Morphologic index: Schwalbe (15) introduced an index of the ear which is obtained by dividing the ear base by the true ear length. Taking a series of mammals up to man this index increases from 27.6 in the antelope through the kangaroo 33.0, the lemur 76.0, the monkey 84.0–93.0, the chimpanzee 105.0, the orang 122.0, the gorilla 125.0, the negro women of New Orleans 172.67, the negro men of New Orleans 177.9, to the white men of New Orleans 180.2. The Filipino men have an index of 188.9 and the Filipino women 193.96. The index of the Bavarians is 122.0, Great Russians 139.8, Kalmucks 140.6, and Ainos 171.5 (13). The morphologic index is vitiated by the difficulty of finding Darwin's tubercle in a large number of ears. Martin (13) considers the index of doubtful value. The variability is very great, 83.7 to 195.5 in Alsatian men, 97.3 to 189.5 in Alsatian women, 110.0 to 223.0 among the Ainos, and 133.0 to 255.0 among the negro men of New Orleans.

Concha. Measurements and indices

Length: The length of the concha is 24.79 mm. in 56 ears of the white men, 24.25 mm. in 115 ears of the negro men, 24.04 mm. in 29 ears of the negro women, 24.62 in 80 ears of the Filipino men and 23.57 mm. in 14 ears of the Filipino women.

Breadth: The breadth of the concha is 19.14 mm. in 56 ears of the white men, 20.01 mm. in 115 ears of the negro men, 19.24

mm. in 29 ears of the negro women, 17.0 in 80 ears of the Filipino men and 16.93 in 14 ears of the Filipino women.

Index: The index of the concha, as instituted here by me for the first time, is obtained by dividing the length into 100 times the breadth. The index represents the breadth of the concha in terms of the length, the latter always 100. If the index is high, the concha is relatively broad, if the index is low the concha is relatively narrow. The index is 77.21 for the ears of the white men, 82.52 for the ears of the negro men, 80.03 for the ears of the negro women, 69.0 for the ears of the Filipino men and 72.0 for the ears of the Filipino women.

The concha index is more variable among the negroes than among the whites and it is more variable among the negroes than either the physiognomic or morphologic index. The great variations of the concha index need not vitiate its importance, but may add to its significance by indicating the degrees of mixture of negro and white.

The ears of the negro men with a concha index of 81 and over are more like the ears of the negro, because the average total ear length of the ears in this group is 5.6 mm., and the average age total breadth is 3.7 mm., with a physiognomic index of 66.1; whereas the average total ear length of the ears of the negro men with a concha index of 80 and less is 6.1 mm., the average total breadth is 3.8 mm., and the physiognomic index is 62.3, and the ears are therefore like the ears of the white. The concha index is thus proven useful as a racial differentiator of a mixed group.

There is a close correlation between the concha index, the morphologic index, and the physiognomic index.

Descriptive characters (plates 1 to 3)

True negro ear: In addition to the measurable characters of the negro ear there are descriptive characters which are as distinctive as the measurable ones and they may enable the observer to obtain a clearer picture of the true negro ear and its parts (12). The ear is small, almost flat, close to the head, and the helix is broad as if much folded over. The upper part of the helix is almost horizontal and passes almost directly backward from the upper end of the ear base to join the vertical dorsal portion of the helix at a right or acute angle in a rounded point at the upper outer extremity of the ear. The superior and dorsal borders of the helix are separated by a depression above Darwin's tubercle where the helix is thin or absent. The dorsal border passes downward and turns forward at an obtuse angle to form the inferior border of the ear which enters the cheek almost at right angles, with no lobule, or a very small one which is nearly flat (figs. 1–12).

The satyr tubercle is well marked and Darwin's tubercle is small or absent. The skin lines formed by the infolding of the helix are less distinct on the true negro ear than on the white, and they usually converge on the true negro ear over Darwin's tubercle. The concha, like the ear as a whole, is wide and short. The true negro ear, is not seen in great numbers among American negroes. It occurred 245 times among 1478 New Orleans negroes (16.6 per cent), men, women and children, chiefly of the laboring classes.

Involuted ear: There is another form of ear that is found chiefly among the negroes, but it is also found not rarely among other peoples, even among the whites, and I have called this '*the involuted ear*' because it seems to represent an advanced stage in regressive evolution. It is the ear with a broad helix that is much rolled in and frequently has a gnarled or crumpled appearance, as if the ear had been burned around the border and had contracted irregularly in healing, leaving a thick, distorted helix. This ear type in its crumpled condition was at first thought to be due to accidental causes, but the presence of the skin lines of the ear tip in regular order proved the ear to be a true type. This ear form has been described by Fischer as the Hottentot ear (7). It was found 601 times in 1478 New Orleans negroes (40.7 per cent) and 52 times among 857 New Orleans whites (6.1 per cent). The individual characters of the ears of both whites and negroes will next be presented in detail.

Darwin's tubercle: There are three prominent parts of the inner or ventral border of the helix called the Satyr tubercle, Darwin's tubercle and one below this that I will name here for the first time the 'inferior tubercle' of the helix. This tubercle is illustrated by Münch (14) in his study of the development of the ear cartilage. Between these there are two depressions, one at the upper outer corner of the ear between the satyr tubercle and Darwin's tubercle, and one on the dorsal border of the helix between Darwin's tubercle and the inferior tubercle. The three tubercles and the two depressions are made by the unequal turning in of the helix of the ear in the fetus.

Darwin's tubercle is small or absent in the negro, and large in the Filipino, although it is more often absent among them than among the others. It is also small in the white although there are many ears with large tubercles among the whites.

Skin lines on the helix (plates 1 and 2)

The position of the skin lines on the helix caused by the infolding of the tip were first seen in 1914 when I was making the drawings of the ears in figures 1 to 12. These lines have never before been described although they may be seen on practically all adult ears. They converge from the outer to the inner border of the helix beneath the prominence of Darwin's tubercle, or adjacent to it, although they may be seen rarely on the dorsal side of the helix. By their usual position they seem to indicate that the skin has been pulled forward under Darwin's tubercle or has been held there while the adjacent parts of the helix develop more rapidly, leaving lines that represent foldings of the skin.

The lines are more often absent or obscure on the ears of the negroes and Filipinos than on the ears of the whites. The skin lines are more scattered on the ears of the whites and more often occur about Darwin's tubercle on the ears of the others. The lines are also higher up on the helix of the white ears than on the helix of the others, and often appear over the satyr tubercle of the white ear. This may be due to the more regular form of the white ear and to the fact that the satyr tubercle is larger in the negro than in the white, and is turned over from above more in the former than in the latter. This rolling over of the satyr tubercle in the negro ear may prevent the lines from forming above Darwin's tubercle as the latter undegoes retrograde metamorphosis.

The satyr tubercle is large in the negro ear, small in the white ear, and intermediate in the Filipino ear.

The helix of the negro ear is broad, the helix of the Filipino ear is narrow, and the helix of the white ear is intermediate. The broadness of the helix in the negro ear is especially well seen in the upper border in the region of the satyr tubercle, and this border of the ear is horizontal and at right angles to the ear base. There is evidence of greater inrolling of the negro ear in this part, which accounts for the shape of the negro ear, quadrangular, or pentagonoid, and also for its small size, and its greater breadth and less height or length, its short, broad concha, its small base and long true ear diameter.

The lobule is absent or small more frequently from the ears of the negroes and Filipinos than from the ears of the whites, and it is absent or small more frequently from the ears of the women than of the men. Keith (13) gives an increasing size of the lobule in the following order: Orang, chimpanzee, gorilla, negro, British. According to Martin the lobule is absent oftenest in the negroes, less in the Asiatics and least in the Europeans. It is also absent more frequently among the defectives than among normal individual (Bertillon).

The helix and other parts of the ear may be examined for their relative projection from the head, and as this determines in part the Hypo-, Meso and Hyper types of the ear it will lead up naturally to a consideration of these three types.

The negro men have projecting helices, the white men have projecting anthelices, the Filipino men resemble both the white and negro men, and the negro and Filipino women resemble the white men more than they do the negro men.

The lobule and the inferior border of the helix: This part of the ear is turned from the head in the negro men, and in toward the head in the white men, and the negro women resemble the white men in this respect.

The posterior auricular sulcus: The sulcus turns into the concha in the negro men, out over the helix or lobule in the white men, and in the Filipino men it does both. The negro and Filipino women are like the white men in this respect.

Tragus and antitragus: The negro men's ears have depressed or intermediate antitragus and tragus, and the white men's ears have prominent ones, in which the ears of the Filipino men and women and the negro women resemble the white men.

Asymmetry: (8) The ears of the negro men are asymmetrical in 33.3 per cent, and asymmetrical in 66.7 per cent; the ears of the negro women are asymmetrical in 30.0 per cent, and symmetrical in 70 per cent, and the ears of the white men are asymmetrical in 25 per cent and symmetrical in 75 per cent. This does not include slight differences, but only such as an oval ear on one side and a pentagonoid ear on the other, or the absence of lobule on one side and its presence on the other, etc. The ears of the two sides are almost invariably asymmetrical in a slightly different arrangement of the skin lines, different curves of the helix, depths of the concha, etc.

Résumé: The details of the ears of the negro and white are different as follows: The negro ears are glabrous, the white ears are hirsute; the satyr tubercle is large in the negro ear, small in the white; Darwin's tubercle is more difficult to find in the negro ear than in the white; the skin lines converge about Darwin's tubercle in the negro ear, and between Darwin's tubercle and the satyr tubercle in the white; the helix is broad in the negro ear, narrow in the white; the anthelix is more prominent in the white ear than in the negro; the posterior auricular sulcus is deeper in the negro ear than in the white, and in the negro ear the sulcus dips into the concha, whereas in the white it turns out over the helix or lobule. Also in the white ear the helix and lobule are turned towards the head and are not prominent, and the tragus and antitragus are turned away from the head and are prominent, whereas in the negro the reverse is true. The white ear is also more symmetrical than the negro, and the negro ear is involuted, whereas the white ear is not. All of these characters are mixed in the Filipino ears, evidence of Negrito and European stock as their basis. The true negro ear and the involuted ear are characteristic negro ears, and they both represent great regression in evolution. This regression is represented by the involution of the helix, which is turned in and is broader in the negro than in the white. The involution is present on the few fetal negro ears I have examined as early as the third or fourth month at which time other negro characteristics are present. For this reason it seems to be rather a condition of regression in evolution than of retrograde metamorphosis in development. The small size of the negro ear, the great breadth and irregularity of the helix and the absence of hair all point to the negro ear as more advanced in regressive evolution than the white, and further removed from the apes.

Three fundamental ear types (plates 1 to 3)

It should be plain from the foregoing that the ears of the Filipinos, negroes and whites are different, and the form of the true negro ear, and the involuted ear should be clear, but there are other forms than these among the ears examined, forms that are characteristic of three types of white ears, but that may and do appear among all peoples of the world. The three types I have called the Hypo-, Meso-, and Hyper- types, and each of the three types may be subdivided into onto-morph and -phylomorph forms, the phylo, the primordial form and the onto, the derived form. At birth the white child is a Hypo-phylomorph, and as the child develops its passes consecutively through the stages of the Hypo-onto-morph, Meso-phylo-morph, Meso-onto- morph, Hyper-phylo-morph and Hyper-onto-morph, unless development stops at or between one or the other of the types. This is a process of differentiation and not of growth, because the Hyper-onto-morph, which is apparently the most highly differentiated type, is the smallest when the adult state is reached. The Hyper-onto-morph, the Meso-onto-morph, the Hyper-phylo-morph and very rarely the Hypo-onto-morph are European, or white, types in the adult; whereas the Hypo-phylo-morph, the Meso-phylo-morph, and rarely the Hyper-phylo-morph are types of the negroes, Filipinos, and other primitive peoples.

It may be clearer to omit these distinctions at this time and to confine the grouping of the three types, Hypo, Meso, and Hyper, which are readily distinguishable. When this study was begun and the observations made, first the ear type was written down on the card for the ear to be described, then each part of the ear was described in detail, the skin lines, hair, Satyr tubercle, Darwin's tubercle, helix, anthelix, posterior sulcus, tragus, antitragus, lobule, etc. From the data thus obtained the following facts have been collected:

Hypo (plate 3): The helix is prominent, the lobule turns away from the head, the anthelix is intermediate, and the tragus and antitragus are depressed in the Hypo ear, therefore the ear is bowl-shaped or trumpet-like. The flaring ear of the other types must not be mistaken for the Hypo ear, because the flaring ear is due to a wide dorsal wall in the concha, which makes the ear stand out, whereas the Hypo type of ear is due to a greater rolling over of the helix all around to the lobule which forms a shelf. This is not the extreme and disordered rolling over of the helix as in the true negro and involuted ears, but the helix presents the form of a round roll like a thickened and turned in edge of a bowl or trumpet.

Hyper (plate 3): The helix and lobule turn towards the head, the anthelix is prominent and the tragus and antitragus project from their surroundings in the Hyper ear. The helix is thin all around, and has turned in very little except at the upper part, and even this is not rolled in to a great extent. None of the tubercles of this type of ear are large, due to the slight development of the helix. It looks as if the helix had stopped developing early and the other parts of the ear had continued to develop which results in a contracted helix, and as the helix had not rolled in enough to contract forward, it turns backward more or less behind the ear. The edge of the helix has a semispiral or italic f shape, or the shape of the old English letter *s*, when the ear is viewed from behind. This type of ear is the most distinctive of the three and the type of individual called the Hyper-onto-morph is the most distinctive of all individuals. It is that type which is small, thin, wiry, and nervous, with long narrow head, long narrow nose, long narrow face, with pointed chin—the 'hatchet face,' as the Australians call the Englishmen in derision. This type has been found by me to have a very short intestine, sometimes only twelve feet in length, and it has also been found to have a low pylorus and duodenum, a low hepatic and splenic flexure of the colon, and a low transverse colon. The suggestion has therefore been advanced by Goldthwait, Brown (4) and others that the Hyper-onto-morph is immature, an under-developed individual morphologically. Also that it is the carnivorous type of Treves and others. There can be no doubt that the type is the end product of a hyperactive thyroid gland. The individuals are prococious in the development of the teeth, nose, face, head, and general body form (3). Their development may be so rapid that such structures as the ears, stomach, small and large intestine fail to finish their growth and transformation. Other evidences of thyroid activity are that the individuals are nervous, high-strung, and very active mentally, and there is a low grade of exophthalmos, the eyes are wide open and often present the wild look of a surprised animal, a condition that has been noted especially among the Indo-European women, and is considered to be a mark of beauty. They are susceptible to diseases of the alimentary canal, nervous system and lungs (epitheliopaths), as well as exophthalmic goiter. They have small bones and there is evidence of calcium insufficiency due to the thyroid secretion.

The Hyper type I have called an epitheliopath, and the Meso a mesotheliopath, because of the susceptibility of the epithelial tissues to disease in the Hyper type and the susceptibility of the mesothelial tissues to disease in the Meso type. Goldthwait of Boston has carried my work further and has demonstrated that a large majority of the inmates of insane asylums are of the Hyper type and that this type is susceptible to joint affections. Percy Brown of Boston has demonstrated associated alimentary diseases with the Hyper type (4), and Bryant of Boston has utilized the Hyper and Meso type in a successful rational diet, feeding the Hyper on concentrated nutrition, meat, eggs, and milk, because the intestine is short, and feeding the Meso on coarse bulky foods because the intestine is long. I may add the results of measuring the intestine in the dissecting room during the past two years (2).

Fourteen subjects of the Hyper type have an average length of 17.2 feet for the small intestine, the shortest 10 feet and the longest 27; eleven subjects of the Meso type had an average length of 23.3 feet for the small intestine, the shortest 16.3 feet and the longest 29.5; and 27 subjects of the Meso-Hyper type have an average length of 20.8 feet for the small intestine, the shortest 16 feet, the longest 29 feet. Only one subject of the Hypo type had the small intestine measured, and the length in that one was 16.9 feet. The lengths are only approximate because of difficulties in measuring, but the condition is evident and the correlation positive.

The Hyper type of ear and the Hyper type of person may be looked upon as the result of rapid transformation with slow growth, and the Hypo type of ear and the Hypo type of person may be looked upon as the result of slow transformation with rapid growth. We are reminded of the work of Gudernatsch (10) and his feeding experiments with tadpoles, in which he obtained the Hyper type of tadpole by feeding tyhroid gland, and the Hypo type by feeding thymus gland. Reasoning from this we may suppose that the Hypo type of man is due to excessive secretion of the thymus gland during development, and that the Hyper type of man is due to excessive secretion of the thyroid gland during development.

In connection with conditions of Hypo-morphism and Hypermorphism, I would like to present observations made from time to time on two children, Mary, aged 7; Helen, aged 2. Mary was the first child, Helen the third. During the first pregnancy there was evidence of increased activity of the thyroid gland in the mother; during the third there was evidence of less activity of the thyroid gland in the mother. Mary was prematurely born about 1 month. Helen was delayed several weeks. Mary has been premature in everything except size, has metamorphosed rapidly but grown slowly. Helen has been delayed in everything except size, has metamorphosed slowly but has grown rapidly. Mary had a Hyper ear at birth, Helen had a Hypo ear at birth. Mary's nose was long at birth and rapidly approached the Hyper form, Helen's was short at birth and has retained the Hyper form. Mary's head elongated rapidly. Helen's elongated slowly. Mary crawled, climbed, stood alone, walked and talked earlier than Helen. Mary's teeth are small and apparently immature, Helen's are large and perfect. Mary is Hyper with rapid metamorphosis and slow growth, and Helen is Hypo with slow metamorphosis and rapid growth. I shall watch with interest their future development.

The Meso ear has a prominent or intermediate helix, lobule and anthelix, and a depressed or intermediate tragus and antitragus. The ear is nearly flat, the bowl is shallow, and the helix is not so much rolled in as in the Hypo ear. The Meso ear type is somewhat intermediate between the Hypo and Hyper types and it may be considered as the fundamental or generalized type of ear from which the Hypo and Hyper type have evolved in different directions.

The Meso ear is usually large and thick and heavy. The helix and anthelix being equally prominent a double roll is formed near the dorsal margin of the ear. The lobule and lower helix turn out from the head in the form of a shelf, and not to the same extent as in the Hypo ear, and the shelf, instead of being horizontal as in the Hypo ear, has a gentle slope forward or may be precipitous. At times the ear is almost flat, and quadrangular in shape.

Hyper-phylo-morph: An ear that is more or less intermediate between the Hyper and Meso types occurs frequently. The Hyper characteristics predominate although in each ear some Meso characteristics may be seen. This is a male ear type because very few appear among the women.

It may be well to determine the relation of the form of nose, head and face to the type of ear.

Nasal index and ear type: The noses of the persons with Hypo ears are relatively broader than those with Hyper ears and the noses of the negroes are broader than those of the whites. The nose of those negroes with involuted ears is about the same as those of the Hyper-phylo-morph type.

Cephalic index and ear type: There is not the same regularity of difference here as in the nasal index and ear type although the negro woman shows the same regularity. In the latter the head is relatively broad in the Hypo and relatively narrow in the Hyper. The heads of the negroes with involuted ears are relatively long and narrow, and as this is characteristic of the negro head in general, we may attribute this to the fact that involuted ears are characteristic of the negro also.

Face index and ear type: The face index is better than the cephalic index as a differentiator, but it not so good as the nasal index. The face of the Hyper is relatively longer and narrower than that of the Hypo or Meso. The face of the white man is relatively longer and narrower than that of the negro man or woman.

EARS OF THE LIVING SUBJECTS

The data for the ears of the Eskimos, American Indians, negroes of Washington, D. C., and 'old whites' (3rd generation or over, in America) came to me through Dr. Hrdlicka, and a part at least has not before been published. The measurements were made of the left ear only, of the Eskimo, by Dr. Riley D. Moore, and of the others by Dr. Hrdlicka. Only the total length and total breadth were taken.

The Eskimo has the longest ears, the Indian is next, the 'old white' third, the New Orleans students fourth and the negro has the shortest ear. Comparing these with the morgue subjects, the latter have slightly shorter ears (white and negro) and the Filipinos have the shortest ears of all. The difference in length between the 'old whites' and the New Orleans students may be due to difference in age as the students are younger and ear length increases with age.

The Eskimo has the broadest ear, the Indian next, the 'old white' next, the student next and the negro has the narrowest ear. Compared with the morgue subjects the living have narrower ears (white and negro) and the Filipinos have the narrowest ears of all.

The Indians have the largest ears, the Eskimos next, the 'old whites' next, the students next, and the negroes the smallest. Compared with the morgue subjects, black and white, the ears of the living are larger, and the ears of the Filipinos are the smallest of all. The small size of the Filipino ears is probably due to the small size of the Filipino people and to the negro (Negrito) mixture. The small size of the negro ear is a racial trait, and is not due to the size of the American negro, who is not a pigmy but almost as large as the American white or American Indian, and larger than the Eskimo.

The negroes have the highest physiognomic index, the students next, the 'old whites' next, the Eskimos next, and the Indians have the lowest index. Compared with the morgue subjects, black and white, the index of the living is less. The Filipino's index is greater than any of the living except the students and negroes, although it is less than the morgue white. By relative physiognomic index the Filipino would be classed with the Eskimo and Indian, and the white in each case is between these and the negro. The Filipino has a large portion of Negrito, which is evident because of the presence of negro and involuted ears in large numbers among them, but the physiognomic index does not show this.

The Filipino, Eskimo and Indian are related to the Mongolian in the physiognomic index of the ear and this relationship is apparently so strong that it is shown in the ear form, in spite of the large share of negro (Negrito) mixture in the Filipino.

The ear length increases with age to 70 years and beyond, and this increase is more appreciable in the white men than in the white women. It is also a little greater in the white men than in the Indian, and about the same as in the Eskimo. The white female and the negro male increase about the same.

The ear breadth increases with age very little and in the negro apparently none at all, but not enough negro ears were measured to establish this. The increase is greatest in the white men.

The physiognomic index decreases with age except in the Eskimo female, the white female decreases less than the white male and the Indian male decreases more than any. The decrease in the index is due to the greater increase in length than breadth of the ear with increasing age.

CHANGES IN THE EAR DURING GROWTH

Fetal stage: The ears of 44 negro fetuses and 22 white fetuses were measured and the total fetal length taken. It is seen that there is a decrease in the physiognomic ear index from 75 to 67 in the white ears, with an increase in total fetal length from 30 cm. and less, to 60 cm., but the negro ears are the same in physiognomic index in all the fetal stages, except from 30 to 39 cm. The index of the negroes is greater than that of the whites in fetal life, and thus early the racial characters are evident. This was also determined by inspection of fetal white and negro ears.

The female fetal ear is longer than the male, and the breadth is about the same as the male, which is what was found in the adult.

Stature and ear dimensions, negro children: It is seen that the length of the male negro ear increases from 49.3 mm. when the stature is 90 to 99 cm., to 56.0 mm. when the stature is 140 to 149 cm., and to 59.1 mm. in the adult. Likewise, the female negro ear increases from 51.8 to 54.7, and to 57.8 mm. in the same periods. The female negro ear is longer than that of the male negro ear until the adult state is reached, after which it is shorter. Likewise, the breadth for the periods mentioned is 33.0, 36.0 and 37.6 mm. for the male negro, and 32.5, 34.3 and 36.3 for the female negro. The female negro ear is narrower than the male and this difference is greater in the adult. Likewise, the physiognomic index for the four periods is 67.4, 64.0, and 63.8 mm. for the male negro, and 62.8, 62.8, and 60.8 for the female negro. The index decreases with growth more in the female from the earliest fetal stages up to the adult, and in this way the negro female approaches the white. The decrease in the index continues throughout life. Daffner (6) gives it in white males as 73.7 mm. at birth, and 58.7 at 70 years of age; and I found it to be 68.1 in the 22 white fetuses and 55.0 at 60 to 69 years of age in the 'old white' American males, and 69.1 in the 44 negro fetuses and 60.3 at 50 to 59 years in the American negro males.

Stature and ear dimensions, adults: It is seen that the length and breadth of the ear increase with increase of stature, the length relatively more than the breadth, therefore the physiognomic index of the ear decreases with increase of stature, except among the negroes where the reverse is true. The breadth of the ear increases more than the length with increase of stature in the negro males, therefore the physiognomic index increases with increase of stature. Thus the negro racial characteristics of the ear are emphasized with increase in stature, purity of ear type goes with tallness in the negro males.

If we take the same stature in each group, for instance the stature of 160 to 169 cm., we find that the ear length, breadth and index are not the same in all the groups. Racial differences appear. The Eskimo and Indian ears are the longest, the negro ears are the shortest, the white are in between in length. The Eskimo and Indian ears are the broadest also, and the white and negro ears are equal to each other in breadth. The result is that the index of the Eskimo and Indian ears is low and that of the negro is high, with the white in between.

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The drawings in plates 1 and 2 were made from the original ears by using the projectoscope with the same focal distance for each drawing. The relative size of the ears and their parts are exact. The ears are reversed, what appears to be the right ear is the left, and vice versa.

PLATE I

EXPLANATION OF FIGURES

1 Right and left ears of a white man, Hyper-phylo-morph, or Hyper-meso, as seen from in front (center figures) and from the side (right and left figures). The same positions of the ears are given in each figure from 1 to 12. Note the skin lines on the helix converge over the folded auricular tubercle (Darwin). Compare these ears with the negro ears of figure 2.

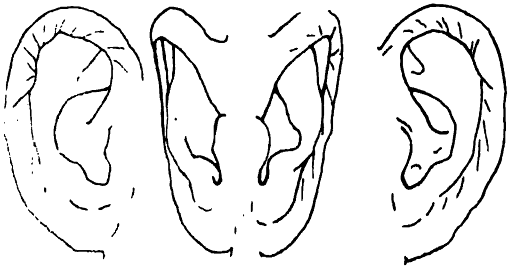
2 Ears of a negro man; the right ear is a true negro ear, the left is involuted. Note the distorted helix, with almost horizontal top, and the skin lines converging over the folded auricular tubercle. Compare these ears with the white ears above and below (figs. 1 and 3).

3 Ears of a white man, Hyper-onto-morph. Note the skin lines and compare the ears with the negro ears above and below (figs. 2 and 4).

4 Ears of a negro man, Hyper-meso. Note the skin lines, and compare the ears with the white ears above (fig. 3).

5 Ears of a white man; the hyper-phylo-morph type. Note the skin lines converging above the auricular tubercle; compare these ears with those of the negro man in figure 6.

6 Ears of a negro man of the Hypo-phylo-morph type. Note the skin lines, with absence of the auricular tubercle; compare these ears with the ears of the white men above and below (figs. 5 and 7).



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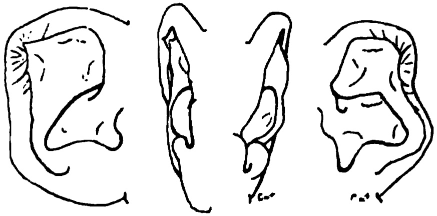

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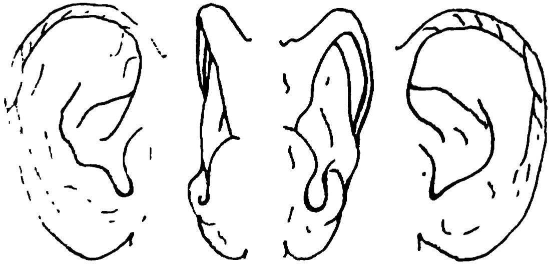

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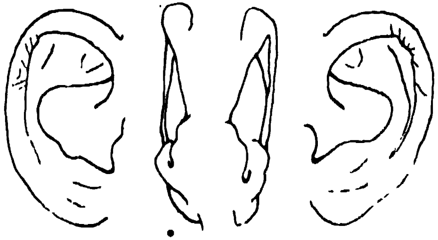

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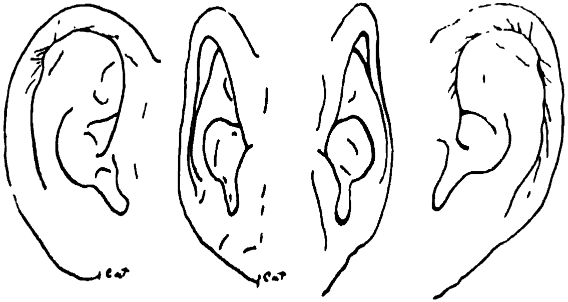

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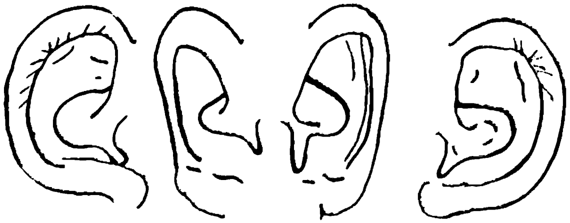

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PLATE 2

EXPLANATION OF FIGURES

7 Ears of a white man of the Meso-onto-morph type. Note the skin lines, with absence of the auricular tubercle; ears asymmetrical; skin lines converge high and low; skin tip is on the lateral border of the right ear. Compare these ears with those of the negroes above and below (figs. 6 and 8).

8 Ears of a negro man, involuted ear form; skin lines scant; auricular tubercle absent. Compare these ears with those of the white man above (fig. 7).

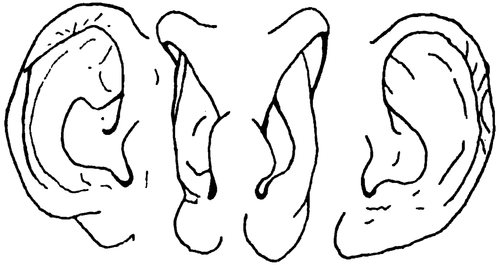
9 Ears of a negro man; involuted ear form. Note the skin lines over the auricular tubercle and the large irregular helix.

10 Ears of a negro man of the Hypo-phylo-morph type. On the left ear the satyr tubercle is very large; the skin lines are scant.

11 Ears of a negro woman of the Hypo-phylo-morph type. Note the horizontal 'top' of the ear, the broad helix and tubercle and the skin lines.

12 Ears of a negro woman; involuted ear form; the satyr tubercle is large on the left ear and on both ears the skin tip is on the dorsal margin of the helix.

PLATE 2



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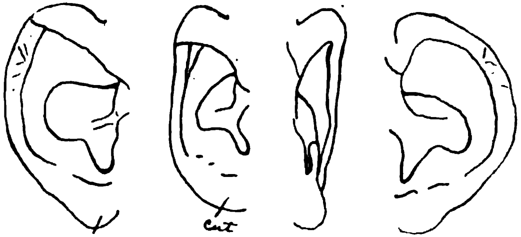

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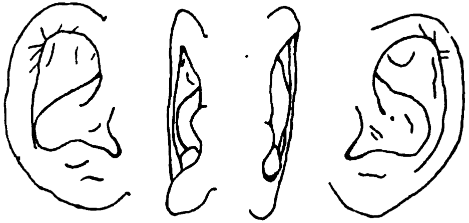

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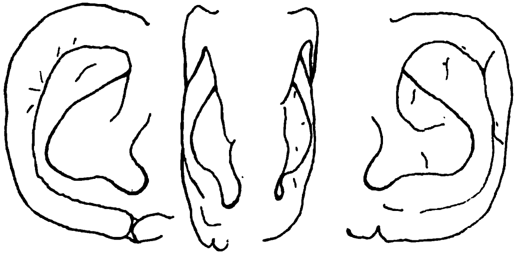

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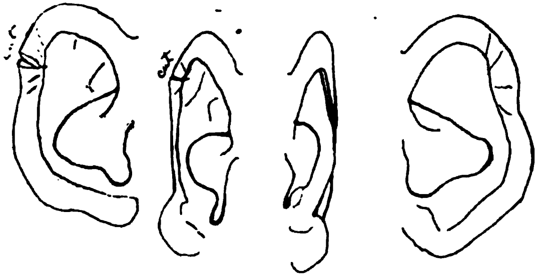

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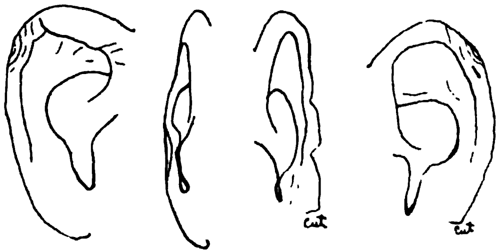

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PLATE 3

EXPLANATION OF FIGURES

13 Ears of a Filipino woman of the Hyper type; see also figure 16 for the front and back views of the same ear. Note the turning back of the helix, the prominence of the anthelix, tragus and antitragus, which are characteristics of the Hyper type. The skin lines are somewhat irregular.

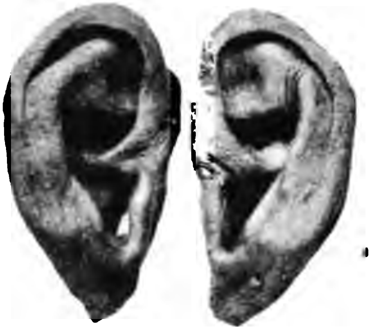
14 Ears of a Filipino man of the Meso type; see also figure 17 for the front and back views of the same ear. Note the large helix, semi-bowl shape, and sloping shelf lobule, which are characteristics of the Meso type. The skin lines are distinct on the left ear, but indistinct on the right, and converge about the auricular tubercle in each ear.

15 Ears of a Russian of the Hypo type; see also figure 18 for the front and back views of another Hypo ear (Filipino). Note the very large helix, much rolled in, forming a bowl-shaped ear, with shelf lobule, depressed anthelix,tragus and antitragus. These ears are both involuted; the skin lines are obscure.

16 Front and back views of the ear shown in figure 13.

17 Front and back views of the ear shown in figure 14.

18 Front and back views of another Hypo ear (Filipino); see figure 15.



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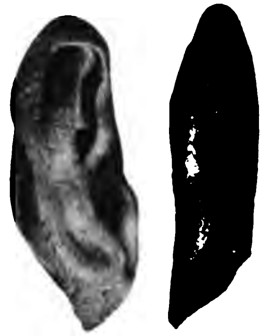

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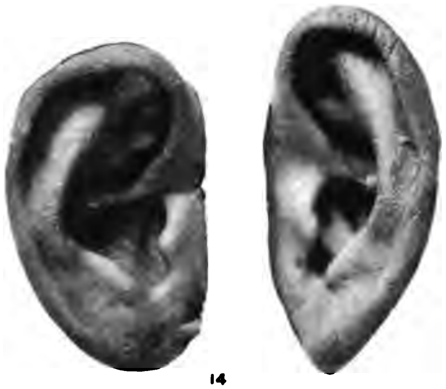

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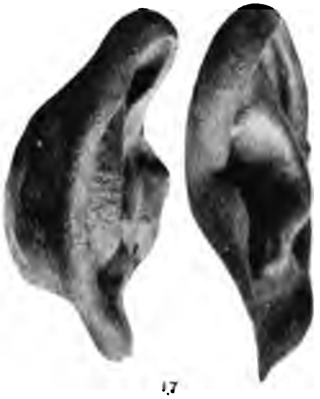

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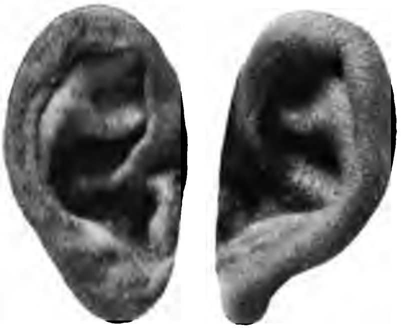

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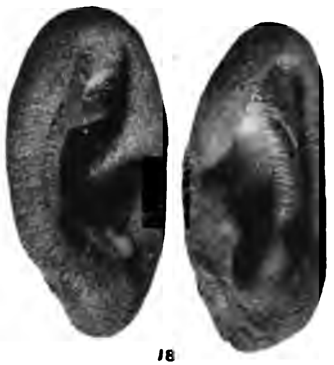

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A MODEL TO ILLUSTRATE THE PROBABLE ACTION OF THE TECTORIAL MEMBRANE

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SEVEN FIGURES

In some studies of the cochleae of the pig, the writer ('08 and '15) became convinced that the tectorial membrane and not the basilar membrane is at least the chief vibratory structure in the mechanism for hearing. With this conviction, the construction of a model was undertaken with the hope that it might illustrate something of the possible behavior of the mammalian tectorial membrane when energy represented by sound waves is imparted to the fluid in which it lies.

Of the many experiments with apparatuses and the several models described by others, none have attempted to reproduce the form and arrangements of the parts of the actual auditory apparatus and but little of the conditions under which these parts are supposed to act in the animal. It seemed to the author that more instructive indications of the process of hearing might be obtained with a model in which the outer, middle and inner divisions of the peripheral part of the auditory apparatus are represented and the forms and relative arrangements of the structures comprising each division imitated, and a model to which might be applied the disturbances giving rise to sensations of sound in the actual ear. The construction of such a model must necessarily be preceded by detailed studies of the structures of the ear and especially of those structures considered acted upon by sound waves in a way to arouse the various sound impulses in the auditory neurones. Also it seemed advisable that the studies of the structures be carried to the labyrinths of adult animals, rather than confined to those of foetuses, and the writer's paper of 1915 describes some observations upon adult cochleae, chiefly those of the adult hog.

The purpose of this paper is to describe a model and to mention some of the results obtained with it suggesting the action of the tectorial membrane when actual sound waves are applied to the tympanic membrane. It is thought advisable to precede this description by a brief résumé of the anatomical observations made in previous papers which have led to the conviction that the tectorial membrane is the structure best adapted for the vibratory activities required. The model lays no claim to completeness of plan. Both its form and excellence of construction leave much to be desired. Consideration of only the few simpler and most evident of the results obtained with it will be undertaken. Many of the phenomena it presented appeared so mixed and complex in the physics involved that, considering the great coarseness and imperfection of the model as compared with the cochlea itself, attempts to interpret them seemed needless as well as almost hopeless. Some figures are given for review of certain of the anatomical features mentioned as well as figures to illustrate the construction of the model. Citations to most of the literature consulted are given in the previous papers and but few of these will be repeated here.

RÉSUMÉ OF THE THEORIES OF HEARING AND OF OBSERVATIONS UPON THE SUPPOSEDLY VIBRATORY STRUCTURES RELATED TO HEARING

It is considered established (1) that the cochlea is the essential organ of the peripheral part of the auditory apparatus, that it contains the neuro-epithelium in which auditory impulses are aroused and is generally thought to be so constructed as to be especially capable of serving, in conjunction with the central nervous system, in the analysis of sound; (2) that the auditory impulses imparted to the fibers of the cochlear nerve are aroused in the hair cells of the neuro-epithelium (organ of Corti) by impingement of the hairs of the hair cells against the basal surface of the tectorial membrane, and that the impingement results from vibratory motion induced by that form of atmospheric disturbances known as sound waves; (3) that sensations of sounds of the highest pitches of which the apparatus is capable are mediated by the basal end of the coil of the cochlea. For example, Munk destroyed the basal end of the spiral organ in dogs, operating through the fenestra cochleae (rotunda), and found deafness to high notes to result, and Baginski destroyed the cochlea of one side entirely and then operated to destroy parts of the cochlea of the other side, obtaining results confirming those of Munk.

The most commonly accepted theories of hearing may be divided into two: that elaborated by Helmholtz, comprising ideas involving phenomena of resonance purely, and the Telephone Theory, comprising ideas involving little or no resonance.

One of the earliest advanced ideas was that the hairs of the hair cells are themselves agitated selectively, or in resonance, by the different sound vibrations imparted to the cochlea. This was quickly abandoned as untenable on the ground that the hairs are neither suitably constructed, long enough, nor vary sufficiently in length to be effectively acted upon by the vibrations as transferred to the endolymph in the cochlear duct. The Helmholtz theory is a resonance theory wholly and was applied solely to the basilar membrane, that narrow, thinnest span of the membranous spiral lamina. Practically all who have tried to apply it to given phenomena have had to modify it. Based upon erroneous descriptions by others (Nuel, 1872, for example) of the basilar membrane as composed of independent, radially disposed fibers and upon the fact that the membrane increases in width (in length of the fibers) in passing from the basal to the apical end of the cochlea, the theory requires the sympathetic or selective vibration of these fibers in resonance with the various vibration frequencies imparted to the endolymph. The hairs of those hair cells resting over fibers of the basilar membrane with a length, or natural vibration frequency, corresponding to the vibration frequency of a given note, were thought to be thrown against the basal surface of the tectorial membrane by the selective vibration of such fibers. Thus the theory assumed that the basilar membrane is composed of fibers of lengths varying according to the vibration frequencies of all the sounds the organ is capable of appreciating, that mixtures of sounds are analysed in the cochlea by the resonant vibration of the fibers in different parts of it corresponding to the different tones contained in the mixture.

Aside from the many physiological difficulties met in applying it, the Helmholtz theory is not supported by the later found anatomy of the cochlea: (1) The basilar membrane is not composed of independent fibers. The structure given the name is composed of three layers of white fibrous tissue, one of which courses at right angles to the others. That part of it which is radially arranged is nothing more than a flat tendon, the fasciculi of which are abundantly connected with each other by collateral branches. (2) Were the basilar membrane composed of radial fibers capable of vibrating independently, it is blanketed on both its sides by continuous and thick layers prohibitive of any such action. On its apical or vestibular side is spread the spiral organ (of Corti) and the membrana propria of its epithelium; on its basal or tympanic side extends the continuous layer of epithelioidal syncytium with its blood vessels and the continuous endothelium lining the scala tympani. (3) Were the membrane as the theory assumes, the cells of the spiral organ are so closely associated and cemented together that individual hair cells or groups of hair cells overlying the fibers concerned with a given note could not be made to impinge separately against the tectorial membrane by the resonant vibration of the fibers. (4) It is questionable whether the fibers, were they independent and free, are long enough for the resonant vibration assigned them by the theory, especially for the sound waves of the lower notes appreciated. Liberal measurements in the human cochlea give the supposedly vibrating part of the membranous spiral lamina a width of only $\frac{3}{10}$ mm. (304μ) at its apical end where it is broadest and $\frac{3}{18}$ mm. (168μ) at its basal end. Measurements of the same for the adult hog gave 258μ as the average width at the apical end and 185μ as the average width at the basal end. Helmholtz himself appreciated the doubt whether fibers so short as the width of the basilar membrane can be thrown into vibration by sound waves. (5) Sometimes in the cochleae of the pig, and perhaps other mammals, a part of the organ of Corti in the basal end may rest upon the bony spiral lamina instead of the basilar membrane.

The idea involved in the telephone theory was first suggested by Rinne in 1865, or about thirty years before the elaboration of the Helmholtz theory. It was more fully worked out by Rutherford in 1886 and since modified by Waller in 1891, Meyer in 1898, Ewald in 1899, Gray in 1900, and others. Originally it assumed that the vibrations imparted effect the cochlea as a whole. Rutherford at first suggested that all the hairs of the hair cells are thrown into vibration by each note and the impulses thus aroused in the cochlear nerve are merely similar in frequency, intensity and quality to the vibration frequency, amplitude and quality of the notes acting upon the apparatus. Therefore, the analysis of sound would be wholly cerebral. This idea that the impulses are aroused by the hairs being acted upon directly was early abandoned by Rutherford and the telephone theory became applied to the basilar membrane and all the later modifications of it have applied it to this membrane. Waller and Meyer assumed that the vibrations as transferred from the tympanic membrane to the endolymph of the cochlea affect the basilar membrane as a whole. Meyer supposed that the wave motion produced by each note, as it passes in the scala vestibuli, affects an extent of the basilar membrane just in the proportion that the amplitude of the vibration is not decreased by the resistance to be overcome in its passing toward the apex of the cochlea. Thus certain wave motions will affect greater extents of the basilar membrane than others and therefore will cause the hairs of a greater number of hair cells to impinge against the tectorial membrane. Waves of lesser amplitudes (intensity), in overcoming the resistance met in passing from the basis of the stapes toward the apex, earlier become too faint to sufficiently agitate the basilar membrane, each note involving an extent of the membrane according to its amplitude or intensity. In this idea pitch depends upon the vibration frequency (the number of stimulations of the hair cells per unit of time) and intensity is expressed in the total number of hair cells (extent of membrane) irritated. Obviously some analysis of sound may thus be made in the cochlea.

The telephone theory differs from the Helmholtz theory in that the latter supposes the basilar membrane composed of fibers of varying length, those of given lengths vibrating in resonance with waves of given vibration frequencies, making entire analysis of sound by the cochlea possible, while the telephone theory as now modified assumes that the basilar membrane vibrates as a whole to every note in such extent as the amplitude of the wave motion and the resistance to its propagation will allow, the auditory neurones transmitting to the brain impulses of frequencies and intensities corresponding with those of the vibrations concerned.

Leave is here asked to submit below a modification of the telephone theory applied to the tectorial instead of the basilar membrane. Siebenmann ('98) seems to have first recognized the importance of the tectorial membrane in the auditory apparatus, noting that it begins in the animal series with the beginning of 'musical hearing' and that its absence or deformity results in deafness. He was the first to suggest that it may be thrown into vibration by sound waves. Von Ebner ('02) suggested that the tectorial membrane, especially its free zone, may serve as a mechanism for sympathetic vibrations. Following von Ebner, Kishi ('07) and Shambaugh ('07) attributed powers of resonance to the tectorial membrane but considered it attached to the spiral organ and composed of independently vibratory elements ('lamellae').

The anatomical studies undertaken by myself have had to do with the tectorial membrane of the foetal and adult pig and the adult ox, rat and human. Most of them have been made upon cochleae of the pig. My conviction that the tectorial membrane is by form, nature and position the best adapted of the structures in the cochlea for the vibratory activities required in the process of hearing is based upon the following observations:

(1) The tectorial membrane is strictly coextensive with the spiral organ (organ of Corti). It is developed in company with

and from the same variety of cells as the spiral organ (both being of ectodermal origin). The so-called basilar membrane is not always coextensive with the spiral organ.

(2) In position, the tectorial membrane lies over the apical or vestibular surface of the spiral organ and thus may be first and more directly acted upon by the usual sound vibrations, since these are imparted by the basis of the stapes directly to the fluid in the scala vestibuli. The basilar membrane lies under the basal side of the spiral organ and next the scala tympani, the thick spiral organ, the tectorial membrane and the vestibular membrane intervening between it and the scala vestibuli.

(3) In the other sense organs, and all sensitive surfaces, the impulses are aroused at the peripheral or outer surface of the epithelium. The tectorial membrane lies over the peripheral surface of the spiral organ while the basilar membrane lies under the organ. The membranes of the maculae and cristae, whose origin is directly homologous with that of the tectorial membrane, arouse impulses at the peripheral surface of their respective neuro-epithelia.

(4) When the two are teased out for examination in the fresh, the tectorial membrane is found to be far more flexible than the basilar membrane.

(5) The tectorial membrane is considered more adapted for application of the telephone theory, capable of being more freely agitated, in that one edge of its supposedly vibratory portion, its outspanning zone, is free, while the basilar membrane is merely a flat tendon, one edge continuous from the tympanic lip of the spiral lamina and the other continuous into the spiral ligament. Furthermore, not only are both edges of the basilar membrane attached or continuous with the wall of the labyrinth, but it is loaded on its two sides by thick layers of other tissues likewise continuous beyond its edges and thus it must be less readily agitated than is the tectorial membrane, certainly by the vibrations of lesser amplitude.

(6) Figure 1 is given to show the shape of the tectorial membrane of the adult hog viewed on the flat from the basal surface, its coil slightly opened to obviate the overlapping in its natural

form. It is seen that its vibratory portion or outspanning zone (*OZ*, this figure and figure 2) increases gradually and regularly in width from its basal end (*BE*) to its apical end. Measurements of its width in its different turns recorded in my paper of 1915, show that this zone is about 7 times as wide in the apical as in the basal end. The ends terminate bluntly rounded. Liberal measurements of the width of the basilar membrane (the portion of the membranous spiral lamina supposed to vibrate) show that its apical end is only about 1.8 times wider in the human and averages 1.4 times wider in the hog than its basal end. Measurements of the attached axial zone of the tectorial

EXPLANATION OF FIGURES

REFERENCE LETTERS

AM, 'Accessory membrane'
AS, Adjusting screw
AZ, Attached axial zone
B, Battery
BE, Basal end
BL, Bony spiral lamina
BW, Bony wall of cochlea
BM, Basilar membrane
BS, Basis of stapes
C, Cork
CD, Cochlear duct
CN, Cochlear nerve
CP, Copper plate
CW, Copper wire
ED, Endolymphatic duct
EM, External auditory meatus
FC, Fenestra cochleae (rotunda)
FV, Fenestra vestibuli (ovalis)
GP, Glass plate
GT, Glass tube
H, Horn
HT, Huschke's teeth (edge of vestibular lip of spiral limbus)
L, Boundary line between outspanning and attached axial zone. (Line of imprint of Huschke's teeth)
M, Manubrium of Malleus
MB, Metal Japan button
O, Auditory ossicles
OZ, Outspanning zone of tectorial membrane
PW, Platinum wire
R, India rubber to make water-tight
RC, Cover for organ reed
RT, Rubber tube
S, Switch
SS, Spiral sulcus
SC, Set screws
SG, Spiral ganglion
SL, Spiral lamina (basilar membrane)
S Lg, Spiral ligament
SM, Signal marker
ST, Scala tympani
SV, Scala vestibuli
TL, Tympanic lip of spiral limbus
TM, Tectorial membrane
TpM, Tympanic membrane
WB, Heavy wooden block
WS, Wooden strip
VM, Vestibular (Reissner's membrane)

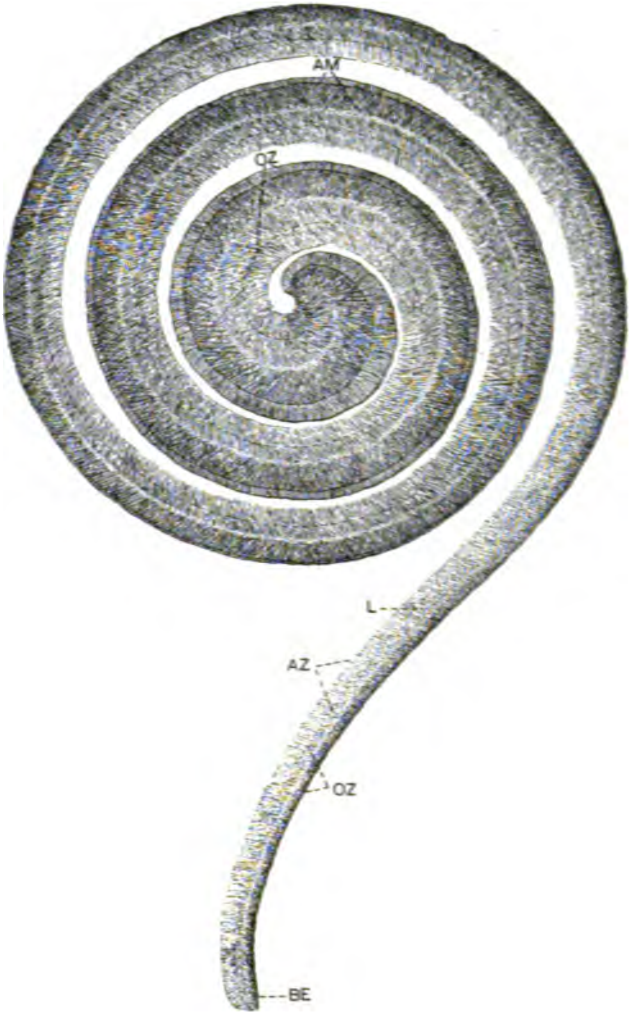


Fig. 1 The basal surface of the tectorial membrane from the left cochlea of the adult hog drawn with the coil opened slightly to obviate the overlapping of its edges existing in its natural coil in the cochlea. Drawing made from several teased out membranes, some whole but slightly damaged in places, others broken in removal and the pieces mounted in their order on the slide.

membrane of the hog (*AZ*, figs. 1 and 2) show that it varies very little in width throughout its entire length. It is slightly narrower in the basal turn. The free edge of the outspanning zone extends well beyond the hair cells in the apical coil but barely over the outermost of the outer hair cells in the basal coil. Section *A* of figure 2 passes some distance from the actual basal end of the cochlea.

Measurements of the thickness of the tectorial membrane, necessarily made from sections of dehydrated and stained specimens in which the membrane was no doubt somewhat shrunken, show that its outspanning zone likewise increases gradually and regularly in thickness in passing from the basal to the apical end and that at the apical end it is 3 times as thick as at the basal end. There is practically no variation in the thickness of the adult basilar membrane; any little variation shown is never regular. The usual variations in the thickness of the membranes are indicated in figure 2, which represents transverse sections of the 1st, 3rd, 5th and 7th half turns in a section of one of the cochleae of the adult hog used for the measurements recorded in the previous paper.

Considering that the usual vibrations are imparted at the basal end by the basis of the stapes, then these vibrations in passing toward the apical end must, according to their vibration frequencies and amplitudes, be damped out in overcoming the inertia of the membrane itself as well as the resistance offered by the walls of the labyrinth and the fluid contained. Thus, it may be argued that the tectorial membrane, varying far more in width and thickness than does the basilar membrane in passing from the basal to the apical end, is adapted for being affected by a far greater variety of vibratory activity, has a much greater possible scale of activity, than the basilar membrane.

Variations in width and thickness are but indications of variations in volume and variations in the volume of the membrane, or the load it carries, are the most important factors to be considered determining the extent to which it may be thrown into vibrations by given vibratory disturbances. Not only must a more voluminous segment absorb a greater amount of energy,

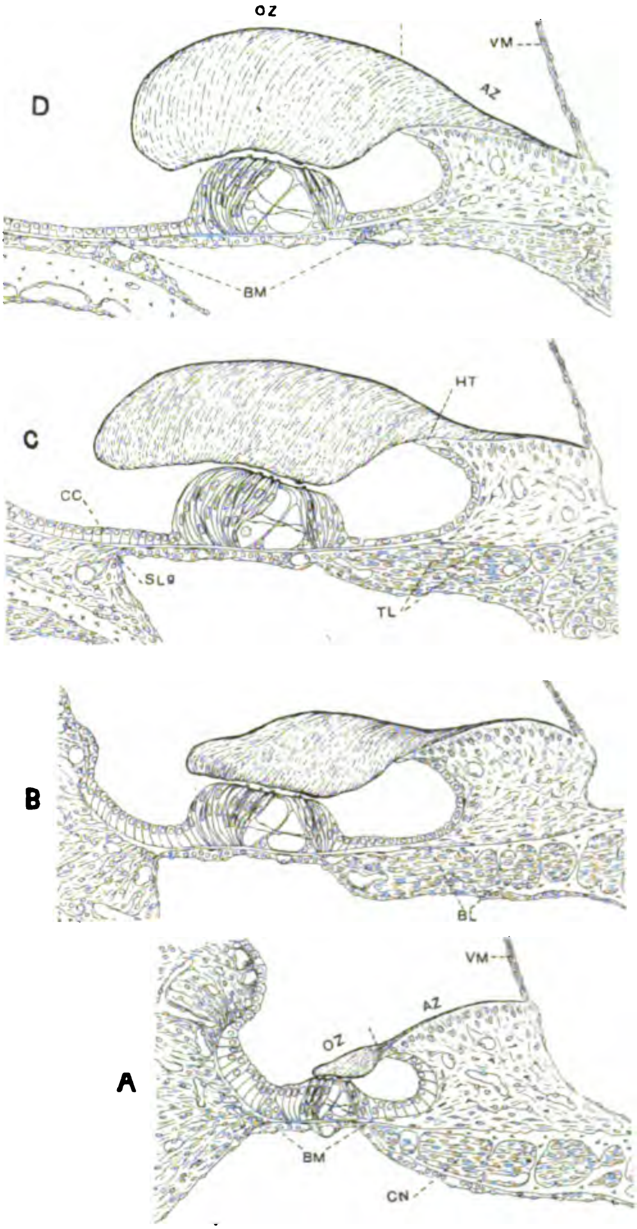


Fig. 2 Transverse sections of the spiral organ and its tectorial membrane taken from one side of a vertical section of the cochlea of an adult hog. *A*, through the 7th half-turn of the coil, represents a section near the basal end of the organ; *B*, *C* and *D* represent respectively sections through the 5th, 3rd and 1st half turns of the coil.

offer greater resistance to being thrown into vibration sufficiently for the necessary impingement upon the hairs of the hair cells, than the less voluminous segment, but it must possess a different natural vibration frequency. The natural vibration frequencies of strips of material, or the vibration frequencies with which they may act in resonance, vary according to their volume or load as well as according to their length. Computations, given in the previous paper, based upon the areas obtained of its transverse sections, suggest that the volume of a given very short length of the basal end of the outspanning zone of the tectorial membrane may increase as much as 40 times in grading to the volume of the same length of the apical end. Calculated in the same way, the volume of the assumed vibratory portion of the basilar membrane at its basal end increases only about 1.4 times in passing to its apical end. The average thickness of the basilar membrane of the adult hog, measured under the spiral tunnel, was found to be 2.8μ. It varies irregularly from 1.8μ to 3.7μ. Usually it is found to be thicker in its basal instead of its apical end.

The length of the tectorial membrane of the adult hog is about 26 mm. It comprises nearly 4 turns.

(7) The shape and attachment of the tectorial membrane may suggest that it is of other use than that of a mere foreign body spanning over the spiral organ for impingement of the hairs against it upon vibration of the basilar membrane. Its outer edge is free in the developed mammalian cochlea; its most voluminous and thus most varying portion is over the organ; it suddenly thins toward its attached zone as though the thinner part of this side of the outspanning zone may serve somewhat as a hinge; and the contour of the basal surface over the organ is always parallel with the apical (peripheral) surface of the organ while other parts of the basal surface are not.

(8) The structure and consistency of the tectorial membrane suggest that it may be especially sensitive to vibrations in the fluid in which it lies and that it may express such disturbances almost wholly in motions vertical to the surface of the spiral organ. It is composed of fibrils imbedded in a gelatin-like matrix

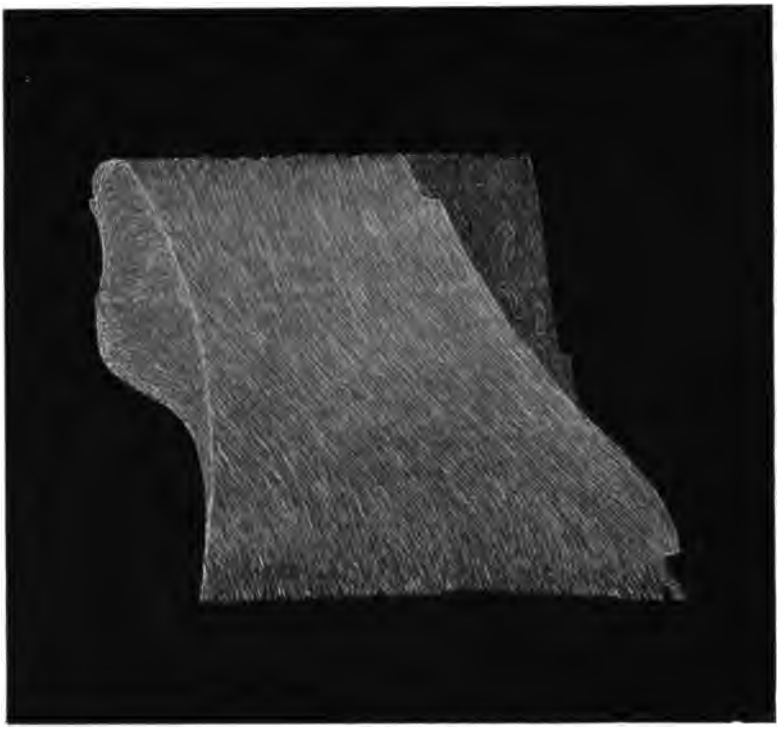


Fig. 3 Piece from the 5th half turn of a teased out tectorial membrane of the pig viewed from its apical surface. Given to show more nearly the actual appearance of the membrane as seen over a black surface and to show the course of its fibrils embedded in the matrix. The right hand side of the figure represents the appearance presented where the membrane had been torn across in teasing. The cut surface shown in the left side was not drawn from this specimen but added onto the figure as suggested in the vertical sections of this turn of the coil. The bottom part of the figure represents the attached axial zone of the membrane. The line showing through the outspanning zone is 'Hensen's stripe.'

and its specific gravity appears practically the same as that of the endolymph in which it lies. Its fibrils are not arranged in it transversely but course in it obliquely, their direction inclined toward the apical end. Those in its apical side are more inclined toward its apical end than those in its basal side, thus intercrossing in the structure of the membrane rendering it less fragile for, in teasing it out even after fixation, it never breaks transversely but always tears apart (fig. 3). In its natural state, it is most inconceivably flexible. In the cochlea while being teased out and in the water under which it is teased, it becomes tangled or adheres to the needle at the slightest touch with most exasperating readiness. In the fresh state especially, it is extremely sensitive to agitations of the fluid surrounding it. This flexibility is much greater in the transverse directions. While wafted about in the water of the dish it manifests sufficient elasticity for its apical turns to resume their normal coil before it settles upon the bottom of the dish. Its thinner basal turn will not do so. It manifests considerably more elasticity in the direction of its width, or against stress applied parallel to its length. Except where it may become twisted, even its very thin axial zone is never found folded upon itself in mounts of the whole membrane nor in pieces of it. With its thin axial zone adherent upon the vestibular lip of the spiral limbus, this latter elasticity is considered sufficient to hold the outspanning zone in its position in proximity to the hairs of the hair cells whatever the position of the head of the animal, especially since the membrane manifests a specific gravity but very little greater than the fluid surrounding it. It is suggested that this greater elasticity in its width may allow a delicate spring-like action of the thinner axial part of the outspanning zone, and the adjoining part of the attached zone which overlies the projecting edge of Huschke's teeth (*HT*, fig. 2, *C*). Such action may aid in controlling such undulatory motion as the outspanning zone may assume. The form of movement of this zone is suggested to be possibly coarsely represented by that of a flexible ribbon attached along one edge and immersed in water, plus the elasticity and varying proportions manifest in the tectorial membrane.

In constructing the model, the following considerations were in mind.

The spaces within the cochlea are completely filled with lymph in the normal condition. The vibratory motion imparted to this lymph by the basis of the stapes must be of the form shown by experiment to be propagated in a column of water upon percussion at one end of the column, namely in the form of compression waves, or alternate phases of condensation and rarefaction, moving longitudinally. The pressure under which the endolymph and perilymph exists is probably the same as the general blood pressure of the animal. Should it be greater or less at any time, equilibrium may be regained chiefly by way of the endolymphatic duct and cranio-spinal fluid and by way of the blood vessels of the labyrinth. Considering the spiral lamina (osseous and membranous) the most rigid partition in the cavity of the cochlea, the two scalae, continuous with each other at the helicotrema, may be considered as a column of fluid along which at least the fainter of the vibrations imparted by the percussions of the basis of the stapes may pass apexward in the scala vestibuli and basalward in the scala tympani. Considering the lymph in the labyrinth as incompressible by such force as may be imparted to it by the basis of the stapes, pressure resulting from strong pulsations of the stapes may be compensated or relieved by the membrane over the fenestra cochleae and also, at need, through the endolymphatic duct by way of the ductus reuniens and sacculus. The membranes bounding the latter and the vestibular (Reissner's) membrane are considered so delicate as to allow scarcely appreciable differences in the vibratory movement in the fluid on their two sides, namely, in the perilymph and endolymph.

Sound waves affecting the tympanic membrane are transformed by the ossicles, the amount of work transferred to the stapes being somewhat controlled by the muscles of the middle ear. The basis of the stapes fits accurately into the fenestra vestibuli (ovalis) and is joined to its bony walls in a piston-like joint. Taking into consideration the difference between the area of the tympanic membrane and the area of the basis of the stapes, together with the leverage afforded by the form and arrangement of the ossicles, it has been computed that the actual force of the motions of the tympanic membrane produced by the atmospheric disturbances may be increased thirty times in its transformation and transference to the perilymph, and that on the other hand the amplitude of the atmospheric vibrations may be reduced as much as seventy times. The amount of the increase in force and the decrease in amplitude depends upon the tensity of the tympanic muscles and also upon the pressure of the air in the tympanic cavity. Thus it may be borne in mind that the vibrations imparted to the lymph of the cochlea by the stapes must *correspond* to the atmospheric waves but *resemble* them only in frequency of vibrations and quality of vibration, for the quality of the vibrations transferred to the endolymph must depend upon the quality or form of the atmospheric vibrations acting upon the tympanic membrane.

The lumen of the scala vestibuli decreases in passing from the base to the apex of the cochlea and that of the scala tympani increases in passing from the apex to the base. The cochlear duct increases in diameter in passing to the apex where it ends blindly. In the adult hog (fig. 4), the space on the apical side of the spiral lamina, namely the scala vestibuli and cochlear duct combined, increases in size in passing from base to apex. The lumen of the scala tympani increases in passing basalward much more than either or both the spaces on the apical side of the spiral lamina, enlarging very greatly in its basal or longest turn. These variations in the lumen of the lymph spaces must result in variations in the resistance offered by their walls to the vibratory motions passing from the base toward the apex of the cochlea. Waves passing apexward in the scala vestibuli are thought to be imparted simultaneously to the cochlear duct, the vestibular membrane between being considered only to control slightly or damp their force as affecting the tectorial membrane. In the cochlea of the adult hog, there appears to occur in the third turn of the coil a slight constriction of the scala vestibuli (fig. 4). This seems present but less apparent in the adult beef but not noticeable in the adult human and rat. No attempt was made to reproduce it in the model, though when present it must make an additional variation in resistance offered to transmission of wave motion toward the apex. The coiled character of the walls of the cochlea must give complicated results of resistance, some of them being no doubt phenomena due to reflections of the vibratory motions. In the model no attempt was made to reproduce the coil of the cochlea because of the difficulties of construction involved. It was decided that such evidences of vibration as could be obtained with the cochlea represented as a straight canal would be suggestive of actual activities though perhaps simpler.

The two scalae are relatively larger in the human cochlea than in those of the hog, beef and rat.

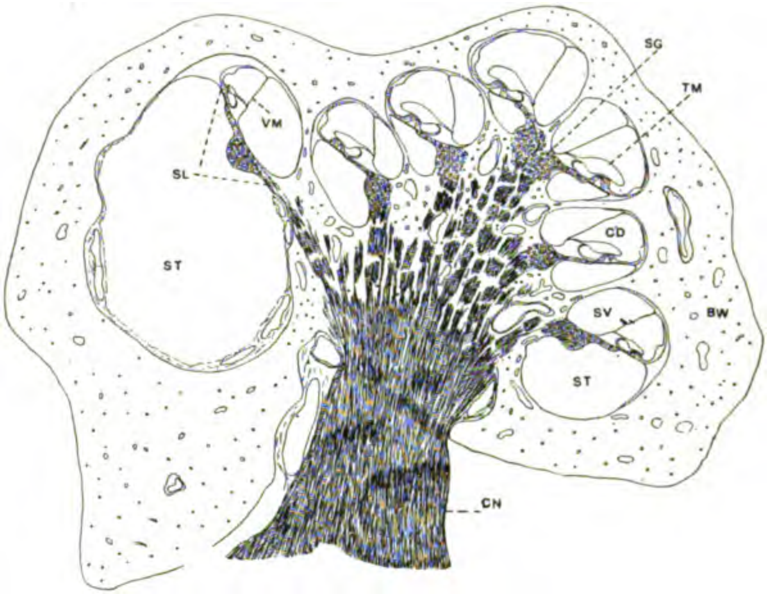
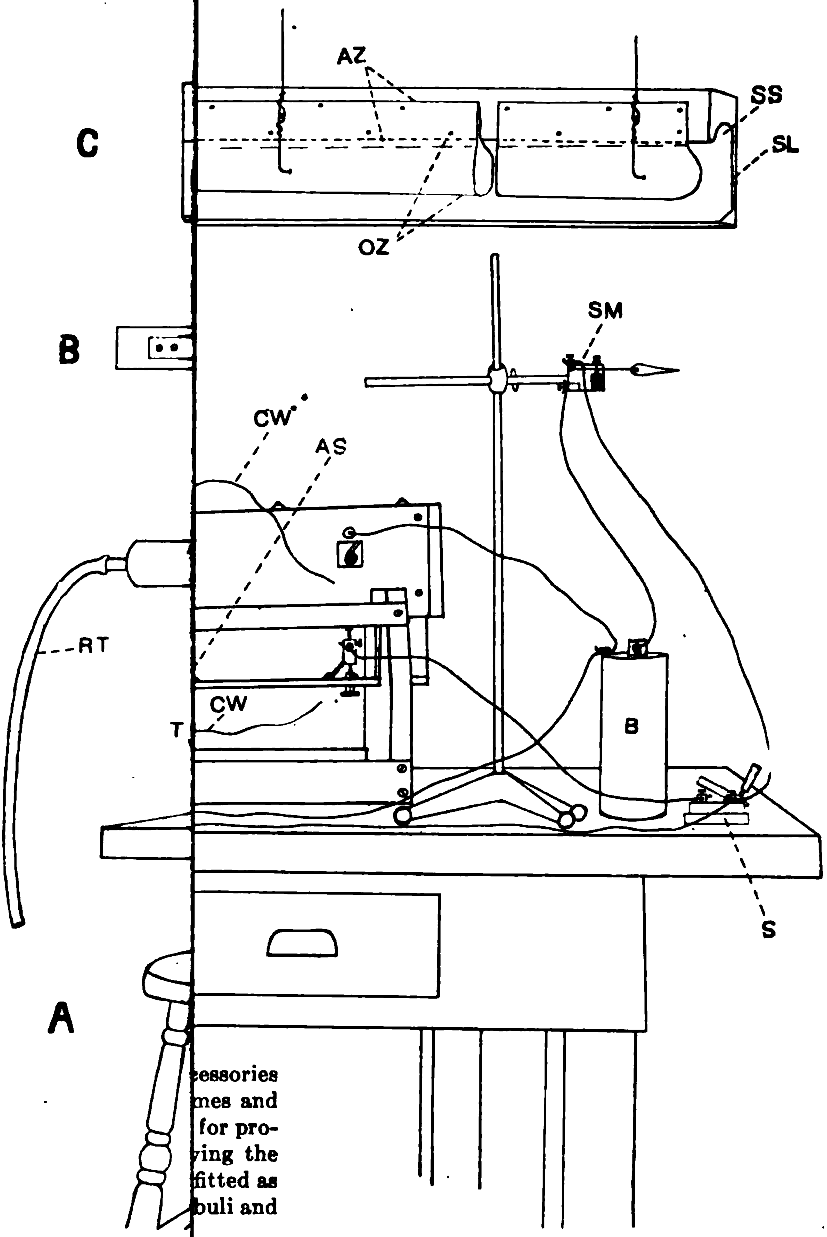


Fig. 4 Outline drawing of a vertical section of the cochlea of the adult hog showing variations in the scalae vestibuli and tampani and in the proportions of the tectorial membrane. For meaning of reference letters, see page 478.

Figure 5, *A*, is a line drawing of the model entire with the accessory parts attached as used in most of the work with it. Figure 7, *A*, shows that end of the model which represents the basal end of the cochlea and figure 6 represents in detail a transverse section of the model.

For the labyrinth of the cochlea, three pieces of wooden board 1¼ inches thick and 44 inches long were so cut and joined together as to make a water-tight trough with inside dimensions of 2¼ inches square and 42 inches long when the ends, cut from the same board, had been put on. The joints, cut as shown in figure 6, were coated with a fresh xylol solution of asphaltum immediately before screwing them together. The spiral lamina, with its membranous portion and its vestibular and tympanic lips was represented by a piece of wood 2¼ inches wide and trimmed out as indicated by *SL*, figure 5, *C*, and figure 6, the spiral sulcus, *SS*, being attained by cutting a lateral groove in the wood. The lamina was fitted as a water-tight partition along the trough, so slanting that the space above it, representing the scala vestibuli, *SV*, figure 6, increased in passing from the basal toward the apical end and thus the space below it, the scala tympani (*ST*) was smallest at the apex and increased in passing toward the basal end. At the basal end (*BE*, fig. 5) the lamina was fitted water-tight against the inner side of the end of the trough, spanning between the openings in this end representing the fenestra vestibuli above it and the fenestra cochleae below it. The basal end of the model showing these openings, *FV* and *FT*, closed by their respective membranes, is illustrated in figure 7, *A*. At the apical end the lamina was cut about 1½ inches shorter than the length of the trough, thus leaving a helicotrema or continuation here of the scala vestibuli with the scala tympani. The top side of the trough could be closed water-tight by means of a plate of glass (*GP*, fig. 6) cut to fit and placed upon strips of India rubber upon which it was pressed down firmly by means of wooden strips placed along its edges and held so pressed by means of metal Japan buttons (*MB*, fig. 5, *A*, and fig. 6) set at intervals along the wall of the trough.

Even an approximate imitation of the tectorial membrane was found very difficult to attain. A material was desired with low specific gravity and a texture sufficiently tough to hold when trimmed to the shape and proportions of the actual tectorial membrane. Gelatin cast in the desired shape and fixed with formaldehyde was tried but the thin, attached axial zone was not sufficiently resistant for the purposes of the experiments nor would the gelatin hold the wires which were decided to be passed through it at intervals for making electrical contacts. Chamois-skin has a specific gravity but little greater than water



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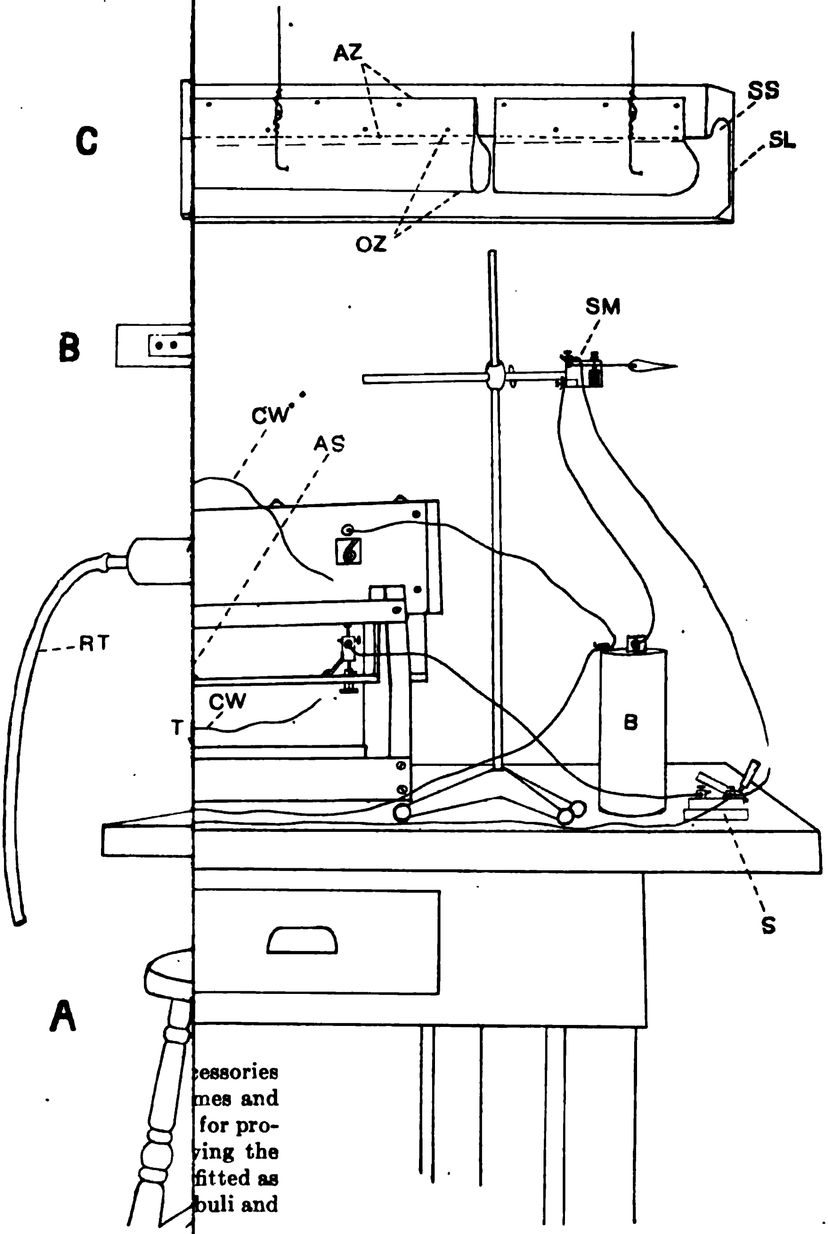

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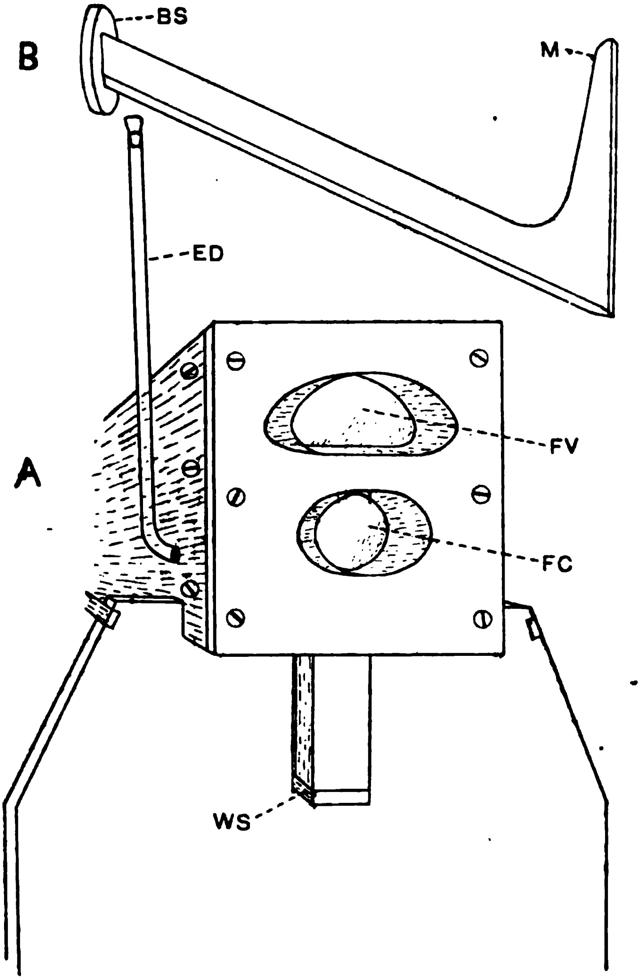

Fig. 7 *A*, line drawing of 'basal end' of model to show the two fenestrae as presented and the position of the 'endolymphatic duct' and the support of the odel. *B*, the form finally used to represent the auditory ossicles. *BS*, basis of apes; *M*, manubrium of Malleus. For other reference letters, see page 478.

when wet and immersed. It could not be obtained thick enough to at all represent the thickness of the tectorial membrane. Some results were obtained in using a strip of chamois skin, one edge of which was turned over to represent the varying width of the outspanning zone of the membrane and stitched down along a line corresponding to the line of the edge of Huschke's teeth, while the remaining width of the strip represented the thin, attached axial zone. The long, tapering sac formed by the turned edge was then filled with a melted 8 per cent solution of gelatin, allowed to set, then fixed in 10 per cent formalin. When immersed, in water this appeared some heavier than was desired but when tacked down by its thin edge along upon that part which represented the vestibular lip and arranged under water in the adjusted model, it gave considerable evidence of vibratory activity. However, after the prolonged soaking necessary to remove the formaldehyde, this contrivance began to show inequalities from beginning disintegration of the gelatin after some time in the water in the model. It of course at no time could be allowed to dry out. Such final results as were obtained came with the use of an imitation but little more satisfactory than the preceding, except that it was more permanent. At a harness factory I found a piece of very thick leather which was said to be elk's hide. It was so tanned as to somewhat resemble the result obtained in chamois skin, being soft and easily wet, and more than usually flexible when wet. Any thick leather tanned by the same process would do as well probably, though there is apparent reason for the impression that the hides of the deer family are more porous than the beef hides. The strip of elk's hide was cut the length and width required and trimmed from the 'flesh side' to the approximate relative proportions of the tectoria' membrane. It was kept in frequently changed water for several days to remove any substances soluble in water. During this washing it was often kneaded to increase its flexibility. Figure 5, *C*, gives an idea of it as tacked down by its thin edge (attached axial zone) along upon the vestibular lip of the spiral limbus. In this figure, drawn in larger scale than the model below, it is shown, to suggest its shape in transverse section, as though two small segments had been cut out. When not surrounded by water in the model, its weight caused it to rest limply upon the spiral lamina below, but with the trough filled with water, its thin attached edge was sufficient to support it in a horizontal position. It may be noted that the outspanning zone is trimmed so as to gradually taper and is made much narrower in its basal end (*BE*).

With the spiral lamina fixed so as to divide the trough into the two scalae, pieces of platinum wire (*PW*) were forced through the outspanning zone of the leather tectorial membrane at six intervals. These wires were bent at right angles and joined by interlocking loops along the inner side of the trough with copper wires (*CW*) which passed through corks driven into holes bored in wall of the trough at the corresponding intervals (fig. 6). The platinum and copper wires were joined by looping them together to avoid as much as possible the additional rigidity that would be given the membrane by continuous wires, the loops being thought to act somewhat as hinges during movement of the membrane. That end of each of the platinum wires which passed through the outspanning zone of the membrane was arranged so that it could come in vertical contact with the surface of a small copper plate (*CP*) soldered onto the end of a heavier copper wire which passed through a small glass tube (*GT*, fig. 6) inserted in holes bored vertically through the spiral lamina and the bottom of the trough below. The passage of the glass tube through the bottom was rendered water-tight by forcing it in surrounded by a piece of rubber tubing, and, for the same purpose, the heavier copper wire passed through plugs of rubber which were forced into the glass tube (*R*, fig. 6). Each of the six heavier copper wires (with the copper plates affixed upon their upper ends) was inserted below into a small brass block and held by set screw, and the lower end of each brass block had threaded into it an adjustment screw (*AS*, figs. 5 and 6) by which the copper plate above could be raised and lowered to adjust the contact between it and the end of the platinum wire. The adjustment screws were held fixed by attachment in a wooden strip (*WS*) extending along beneath the model. To the lower end of each of the heavier wires was attached a piece of copper wire of the same size as that interlooped with the platinum wire above. Thus, a battery interposed between these two copper wires would make possible an electric circuit which could be made and broken at the contacts between the platinum wire and the copper plate by vibrations of the artificial tectorial membrane. Figure 5 shows a battery (*B*) interposed in the circuit of the sixth interval, the circuit of the part of the model representing the apical end of the cochlea.

The object of the similar arrangements of the wires at the 6 intervals was for the experimental determination of the behavior of the different regions of the tectorial membrane toward a given form of vibratory activity imparted to the fluid in the model at its basal end (*BE*). In addition to the necessary use of an ordinary switch (*S*, fig. 5) in the electric circuit, a simple electric signal-marker (*SM*, fig. 5) such as is used in physiological laboratories, and a telephone (*TEL*) were interpolated for use in observing results. A small piece of white paper was glued vertically on the end of the vibrator of the signal-marker that vibrations in it could be more easily seen. The noise of the horn (*H*) usually obscured its clicking to the ear of the observer. The telephone was found to be far more efficient than the signal-marker used. It gave evidence of vibrations of all frequencies whatever induced in the model with sufficient force and amplitude to make and break the circuit, while the signal-marker was found incapable of recording the higher vibration frequencies of which the model was capable. In other words, with the application of sounds of higher vibration frequencies, there could be heard a continuous buzz in the telephone when the vibrator of the signal-marker was practically motionless. An ordinary telegraphic 'sounder' was tried in the earlier stages of the experiments but had to be discarded because found capable of service only with vibrations of lower frequencies.

Before the use of the electric current was suggested, small mirrors were tried with the hope that vibratory activities could be read in the behavior of the small spots of light reflected by them. Thin circular cover-glasses were silvered on one side and cemented with thin asphalt to very minute cork blocks stuck at intervals along the upper surface of the leather tectorial membrane. The apparatus was placed in direct sunlight with the idea that evidences of vibration could be read in the movements of the spots of light reflected by the mirrors upon the ceiling of the laboratory, or on specially devised screens tried later, the long light-levers magnifying the movements. This plan, however, was found disappointing because of the very indefiniteness of its results. The light reflected from the surfaces of the mirrors had to pass through the water in the apparatus and the glass plate of its top side and was so refracted that the boundaries of the spots upon the screen or ceiling were not sharply defined. Continuous vibration could not be distinguished from intermittent, vibrations of higher frequencies were doubtfully discerned and all results seemed exasperatingly confused. The mirrors gave evidence, however, of the first result obtained, namely, that vibrations may be induced by sound waves in a structure imitating the proportions and position of the actual tectorial membrane.

Distilled water was used to represent the lymph in the cochlea. The actual lymph of course differs in viscosity from distilled water and may be better adapted for the conduction of vibratory motion. But in using the electric current for indicating vibratory activity in the model, the fluid used had to be as nearly as possible a non-conductor of electricity. An oil with a low boiling point would of course have been most efficient as a non-conductor, but so far oil has not been used because of the difficulty with which its leakage could be prevented with a construction of the apparatus as here employed and because it was considered that a difference in viscosity between an oil and the lymph would be greater than that of water. It is realized that the ordinarily used distilled water is not absolutely a non-conductor of electricity. Its conductivity is less than tap water and much less than the animal lymph. That the distilled water in use in the model might be as pure as possible, the trough was soaked in distilled water, frequently changed, for about two weeks before the experiments using the electric current began. Further, the water was replaced with fresh at the beginning of each series of trials with the model. Thus since the work extended intermittently through a number of months, it is thought that the water used toward the last at least was fairly free of extracts from the wood and other material used in construction.

Instead of the copper plates employed for contact with the ends of the platinum wires, very small copper cups containing a drop of mercury were at first tried on the ends of the pieces of heavier copper wire. It was found, however, that the movements and changes in shape of the drops of mercury due to changes in surface tension when charged and uncharged seemed to render the contacts less definite and delicate and adjustment of the distance through which contact was made much more difficult than with the use of the copper plates. The plates were kept burnished.

The trough was always filled completely with water. The bent glass tube, *ED*, figures 5, 6 and 7, was put in the model to represent the endolymphatic duct of the labyrinth. It was considered a precaution for compensation in any changes in pressure produced by vibratory pulsations and by changes in temperature. By means of this tube the filling with water could be completed after the glass plate had been put on and pressed down watertight. Remaining air bubbles were gotten rid of through a small hole drilled in the glass plate at its apical end, the hole being closed with a plug of rubber.

The end of the model representing the basal end of the cochlea is shown in figure 7, *A*. The fenestrae were represented by cutting large holes through the wooden end piece and closing these holes with thin skin. To accomplish this cuffs of sheet copper were made to fit the holes and over one end of each of these was stretched and tied a piece of thin raw-hide of the sheep known as 'drum-head skin.' The end of the cuff carrying the skin was driven into the hole till the skin, or membrane, became flush with the inner surface of the trough. Driving in thus made the membranes tense. Then melted wax was poured around the cuffs making their insertion water-tight. The fenestra vestibuli (*FV*; fig. 7) was made oval in shape and larger than the fenestra cochleae (*FC*) below it. These differences were probably unnecessary.

The external auditory meatus (*EM*, fig. 5, *A*) was represented by a wide funnel made from block-tin. A wooden collar was fitted upon the smaller end of this funnel that the tympanic membrane could be stretched over it and secured more safely and easily. For the tympanic membrane (*TpM*), a sheet of that thin preparation of white fibrous connective tissue known as 'Gold-beater's skin' was wet and stretched over the wooden collar of the meatus and bound firmly about it with both twine and rubber bands. The membrane became tense upon drying. The collar was so trimmed that only its periphery was in contact with the membrane, thus making the area of the vibratory part of the membrane greater than the area of the circle formed by the small end of the tin funnel. The area of this membrane was about 30 times the area of the skin closing the opening representing the fenestra vestibuli in the basal end of the model. A tympanic membrane represented by sheet-rubber was found useless in that it absorbed rather than transmitted its vibrations to the "ossicle" pressed against it.

The ossicles of the middle ear were finally represented by a piece of wood trimmed as shown in figure 7, *B*, and figure 5, *A* (*O*), with an oval shaped piece attached to one end to serve as the basis of the stapes (*BS*, fig. 7). At first pieces of hard wood were cut and joined together to imitate the three ossicles with their joints and lever arrangement and with rubber bands for the tensor tympani and stapedius muscles. This arrangement, however, was found difficult to keep in place during the experiments and it absorbed the vibrations of the tympanic membrane considerably more than the single piece shaped as shown. During the experiments, a straight single piece was tried placed perpendicular to the center of the tympanic membrane and to the membrane closing the fenestra vestibuli. This piece was of the same thickness as that illustrated in the figures and its "basis of the stapes" was similar, but its end representing the manubrium of the malleus was fan-shaped and was used extending in both directions across the center of the tympanic membrane instead of having a single arm extending from the periphery of the membrane to its center as shown in figure 5. The planes of the two ends were cut at right angles to its long axis instead of in the form shown in figure 7. It was of interest to find that the vibrations of the tympanic membrane were transferred to the fluid in the model better and more definitely by the arrangement of a single arm extending from the periphery to the middle of the tympanic membrane, similar to the arrangement of the manubrium of the malleus in the mammalian ear, than by the straight piece pressing across the center of the membrane and extending at right angles to both its surface and that of the fenestra vestibuli. The form found most efficient was somewhat similar to the columella of birds.

Sound producers of various types were tried, including pipes giving different tones, trumpets (a cornet and a trombone), horns of different kinds, and finally an assortment of ordinary brass organ reeds. Organ reeds were used chiefly in the work for two reasons: first, instruments producing sound waves by means of vibrating tongues seemed to act upon the apparatus more definitely than any of those tried which gave in other ways the alternate phases of condensation and rarefaction, and second, the vibration frequency of each of the organ reeds was known, the name of the note it produced being stamped upon it. With the other instruments, the vibration frequency of a given sound had to be previously determined by means of a standard tuning fork and the kymograph, used with a writing arm registering the vibrations of the tympanic membrane. The form of the brass organ reed used is shown in figure 5, *B*. In order that its vibrations could be conducted directly into the external auditory meatus, a wooden box or horn (*H*, fig. 5, *A*) was constructed into the end of which fitted a removable cover for the reed (*RC*). This cover was so constructed that reeds could be interchanged at will. Air was blown through the reed by way of the rubber tube (*RT*). The whole sound producing apparatus was held in place by a heavy, ordinary filter stand and no part of it was allowed to touch the model nor the table upon which the model sat. The end of the horn was inserted into the large end of the external meatus but could not be allowed to touch it during the experiments. Trumpets such as the cornet, held in the hand, were merely directed into the meatus.

The external meatus with the tympanic membrane had to be mounted upon a heavy wooden block (*WB*, fig. 5, *A*) and even then it was found necessary to brace it against a cleat fastened upon the table, for certain vibrations of low frequency would cause it to move gradually away from the ossicle pressed upon the membrane.

The adjustment of the distance between the copper plates and the ends of the platinum wires during the experiments was made to the point at which the least movement of either plate or wire would make or break the electric current. Usually a position just at the brink of the make of the current was employed. This could be determined by observing the vibrator of the signal-marker while manipulating the adjustment screws, the battery being interposed.

RESULTS

It was realized that an apparatus so infinitely larger, heavier and coarser in construction than the mammalian auditory apparatus could not be expected to give many results trustworthily representing the behavior of the actual apparatus. Many of the apparent phenomena with the model were so confused and seemed so complex that no attempt will be made to describe them on the ground that they were more the result of imperfections in the model than representing behaviors of the normal apparatus. Interpretations of only the few simpler results will be undertaken and these interpretations will be limited.

I have described the construction of the model in considerable detail with the hope that its repetition with the possible improvements, may be suggested to other investigators and that the experiments may be repeated and extended.

Of the results given by the model indicating the action of the tectorial membrane, the following are considered most directly suggestive.

(1) A structure imitating the tectorial membrane in shape, proportions and environment can be thrown into vibrations by sound waves so applied that their energy is transferred to the fluid in which the structure lies and in a way similar to that employed in the actual ear.

(2) With sounds of low vibration frequency, at least, the tectorial membrane is thrown into vibrations of the same frequency as those of the sound giving rise to them. This fact was determined by allowing the vibrator of the signal-marker to write upon the drum of a kymograph, on which drum had been already traced the vibrations of a standard tuning fork. With the sound waves of higher vibration frequencies by which the model was capable of being acted upon, the signal marker either did not vibrate at all or acted irregularly.

(3) With the distance between the copper plates and ends of the platinum wires adjusted, a heavy step on the floor of the room, a slight blow upon the table or a hand laid upon the apparatus would produce vibrations of the artificial tectorial membrane sufficient to cause a series of makes and breaks of the current. This may be advanced as illustrating the possibility by which sensations of sound are aroused by way of other parts of the body than the tympanic membrane, stimuli explained as conveyed to the bony labyrinth, and thus to the structures within it, directly by way of the skull bones, teeth, etc. Sensations received in this way are among those of lower pitch.

(4) The model showed slightly less sensitiveness to vibrations imparted to the membrane covering the fenestra cochleae (rodunda) than to the same vibrations applied at the fenestra vestibuli. This slight difference is explained as due to damping out effects or absorbtion of the vibrations by the fluid in the scala tympani before they pass directly into the scala vestibuli by way of the helicotrema at the apex of the cochlea.

(5) Jarring of the model and notes of low vibration frequency applied to the tympanic membrane by way of the horn, were found to throw the entire tectorial membrane into vibration. This was determined by interposing battery, signal-marker and telephone at each of the regions of the membrane from 1 to 6,

(positions indicated in figure 5). It was found that all notes with vibration frequencies below that of the note *a* (concert pitch, 220 vibrations per second) resulted in constant vibration of all regions of the tectorial membrane sufficiently strong to make and break the current. This suggests that within the lower range of the natural auditory scale, all sound waves affect the entire spiral organ.

(6) The extent of the tectorial membrane that could be thrown into vibration by certain notes depended upon the intensity or amplitude of vibration with which the note was sounded. For example, the note *g* (196 vibrations per second), the next whole note below *a*, when sounded faintly into the external meatus, failed to result in vibrations of the apical end (region 6) of the membrane sufficient to make and break the current, while if sounded forcibly, this note caused vibrations in all regions. All sounds and notes with vibration frequencies below that of *g* resulted in vibration of the entire membrane, regardless of the amplitude that could be employed. Ewald ('99) applied a modification of the telephone theory to the basilar membrane. He constructed an arrangement in which narrow strips of thin sheet-rubber were adjusted under water and observed with the microscope the behavior of these strips when sound vibrations were imparted to the water. His narrowest strips was 0.5 mm. broad. From the behavior of these strips he suggested that the basilar membrane vibrates throughout its entire length in response to every note applied. The above observation suggesting the action of the tectorial membrane, and the one following, do not fully support Ewald's conclusion for the basilar membrane as based upon the action of his rubber bands. His bands did not vary in thickness, or load carried, along their length. Meyer ('98) constructed an apparatus by which he applied the telephone theory to the basilar membrane. His apparatus was designed to indicate the results of varying amplitudes of vibration rather than varying pitch, using electrical contact and electric lamps as indicators. No attempt was made to imitate the basilar membrane or any other structures of the auditory apparatus. His results led him to conclude that the greater the amplitude of the vibration,

the greater the extent of the basilar membrane involved: that with a faint back-and-forth movement of the stapes only the basal or beginning part of the basilar membrane is set in motion; the greater the back-and-forth movement of the stapes, the further toward the apex of the cochlea will the motion of the basilar membrane extend. This suggestion for the basilar membrane agrees with that offered above as to the behavior of the tectorial membrane, namely, with a note of a given pitch or vibration frequency, a greater amplitude will throw into appreciable vibration a greater extent of the tectorial membrane than a lower amplitude, the extent beginning with the narrower basal end of the membrane and ascending, with the amplitude, along the gradually increasing membrane toward the apex of the cochlea. This action, shown by the model, is one to be expected, since the vibratory motion, imparted at the basal end of the cochlea, necessarily must be gradually absorbed in overcoming the resistance offered by the walls of the cochlea, the inertia of the fluid and the increasing inertia offered by the increasing bulk of the tectorial membrane itself in passing toward the apex of the cochlea. The variations in the diameter of the two scalae in passing from base to apex may result in additional decrease in the efficiency of the vibrations imparted. It is suggested that in the functional scale of any auditory apparatus there must be notes sounded whose amplitudes are gradually decreased by the resistance till the vibrations are completely damped out.

(7) It was further indicated by the model that frequency of vibration or pitch of a sound, considerably more than its amplitudes of vibration, determines the extent or length of the tectorial membrane that may be thrown into vibration. The note *a* (220 vibrations per second) produced with whatever amplitude, would not produce vibrations in the apical end of the tectorial membrane (region 6) sufficient to make and break the current, while it did produce vibrations in region 5. Note *b* (247 vibrations per second), the next whole note above *a*, also produced vibrations in region 5 when sounded with highest amplitude, but none in region 6. Both *a* and *b* produced vibrations in regions

1, 2, 3 and 4. The note *c* ('middle C,' 261 vibrations per second) produced vibrations in regions 1 and 2 but none in the other regions, regardless of amplitude. Judging from the preceding, this note was expected to give vibrations in region 3 at least and I was unable to determine a reason for its not doing so. Also the notes *d* and *e* (294 and 329 vibrations per second respectively) gave vibrations in region 1 but not in the other regions, and the note *f* (349 vibrations per second) at greatest amplitude gave in region 1 only a slight hum in the telephone. Notes with vibration frequencies above that of *f* produced no evidences of vibration in the model. The note *f* and the three or four notes above *f* that were tried produced appreciable vibrations in the artificial tympanic membrane.

Beginning with the note *b*, the signal-marker ceased to be of service with the higher vibration frequencies. At times it would start vibrating at the first puff of the air through the reed and then become silent though a continuous hum might be heard in the telephone. The fact that notes *c* and *d*, *e* and *f* could not be made to give more graded results must have been due to imperfections in the construction of the model. Perhaps the intervals of the membrane arranged for were not short enough. However, such results as were obtained seem to indicate a relation between the vibration frequency of sounds and the extents of the membrane thrown into vibration by them. In explanation of this may be mentioned the familiar fact that of sounds given the same amplitude, those of lower vibration frequency are damped out less quickly in their transmission through a medium, or will travel farther, than those of higher frequency. For example, fog-horns of low vibration frequency or pitch are known to be more efficient for warnings at a distance. Also in atmosphere, sounds of high vibration frequency are not only sooner damped out in overcoming resistance than those of low frequency, but their speed of transmission decreases more rapidly as they become fainter. This damping out must occur much more quickly in transmission through a medium like the endolymph than in atmosphere and in overcoming the resistance offered by the walls of the very small canals of the cochlea and the structures contained within them.

As noted above, the size and volume of the tectorial membrane so increases in passing from the basal to the apical end that the volume or load carried by a given short length of the apical end is about 40 times that carried by the same length of the basal end. This increase seems to occur uniformly throughout, or perhaps a little less rapidly through the basal turn of the coil. It is noted that these variations in the proportions of the tectorial membrane are far greater than can be claimed for any other structures of the cochlea, especially the basilar membrane. Increase of volume or the load carried by a structure means increase of its inertia. The much thinner and narrower basal end of the tectorial membrane extends in the region of the fenestra vestibuli (ovalis), or the region at which the vibrations are imparted to the endolymph by the basis of the stapes. Obviously, a thin, narrow strip offers less resistance to agitation than a thicker, broader strip of the same material. Thus, the thin, narrow basal end of the outspanning or vibratory zone of the tectorial membrane may be thrown into vibration by notes of such high vibration frequencies as would be wholly damped out in overcoming the inertia alone of a more voluminous portion of the membrane. The volume of the outspanning zone of the membrane increases with its distance away from the basis of the stapes and, therefore, among the appreciable sounds of higher vibration frequencies, those of different frequencies must be capable of throwing into vibration different lengths of the membrane, beginning at its basal end. The resistance offered by the endolymph and walls of the labyrinth, as well as the inertia of the membrane itself, contribute to their being damped out at their respective distances toward the apex of the cochlea. Since vibrations of higher frequency are damped out more quickly in transmission through a medium, there may be sounds whose vibration frequencies as imparted to the endolymph are such that they agitate the basal end of the membrane alone sufficiently for the required impingement against the hairs of the hair cells. And, of course, there must be vibration frequencies of similar character but so high as to be damped out by the other structures of the auditory apparatus to an extent rendering them unable to produce effective stimulation of any of the hair cells at all. It is stated that the auditory apparatuses of certain individuals are capable of appreciating higher pitches (vibration frequencies) than others and that certain species of animals have an auditory range including high pitches not heard at all by other species. It is suggested by the model that the lower vibration frequencies may affect all auditory apparatuses. The range of the model extended no higher than the note *f* above 'middle *C*. Considering its relatively enormous size and coarseness of constuction, it is interesting that it had a range so high, even though the end of the horn was inserted directly into the external meatus.

The quality of a note is supposed to depend upon the form of the wave-motion producing it. The peculiar form of a vibration must be represented in its transmission to the endolymph as well as its amplitude and frequency, and the consequent form of the undulations of the tectorial membrane while striking the hairs of the hair cells must give rise to interpretations of quality by the central nervous system. Sensations of pitch must be determined by the number of stimuli applied in a unit of time upon a unit area of sensory surface, that is, by frequency of vibration. Also, among the higher frequencies, it may depend somewhat upon the extent of the sensory surface involved by a given sound: the greater the extent, the lower the note. Intensity of sensation must depend upon the force of the impingement of the hairs of the hair cells (amplitude) and also upon the extent of the sensory surface involved. Of two sounds of the same vibration frequency, that of the greater intensity involves the greater extent of the tectorial membrane. It is suggested that sensations of intensity and quality of sound are produced in ways entirely comparable with those recognized for the other organs of special sense, namely, in all the interpretation of the sensations is correlated with the number, quality and intensity of the stimuli and the area of sensory surface involved.

(8) As to the question of resonance, very little could be determined with the model. The suggestion that, within the

higher part of the range of the organ, notes of varying vibration frequencies involve correspondingly varying extents of the tectorial membrane and that sensations of pitch are determined by the number of stmuli applied in a unit of time to a unit area of hair cells might be so elaborated as to satisfy some of the simpler requirements of the idea that analysis of sound is accomplished in the cochlea or peripheral part of the auditory apparatus.

It is known that the natural vibration periods of strips of material vary according to their proportions: that a thin, narrow strip has a higher natural vibration frequency than a thick, broad strip of the same length, and that a shorter strip has a higher natural frequency than a longer one of the same thickness and width. A load added to a strip lowers its natural vibration frequency. Of the number of musical instruments constructed on these principles, the xylophone may be preferably mentioned here. However, there is no available information as to what would be the behavior of a series of such varying strips joined continuous with each other end to end in their natural sequence, and especially if of a material soft and flexible as that of the tectorial membrane. The tectorial membrane is not only soft and very flexible but its vibrating part or outspanning zone is attached all along one side, and thus its vibratory behavior must necessarily be different from that of a metal or hard-wood strip shaped in the same proportions and lying free as to both its sides. Very possibly, being flexible and attached, the natural vibration frequency of each segment comprising the whole would be modified by that of the segments adjacent to it, that is, the natural frequencies of adjacent regions would overlap into each other as it were, and yet a given region of the whole membrane would have a natural frequency differing from that of another region. If such is possible, then a region would, in its center at least, have a tendency to vibrate in resonance with imparted vibration frequencies corresponding to its own natural frequency. Thus it would be possible that, when the apparatus is subjected to a given sound, a given region of the membrane may vibrate with sufficient excursion to impinge upon the hairs of the hair cells, while regions both above and below it may not so vibrate. In other words, the regions immediately adjacent to that vibrating in resonance, having nearly the same natural periods, might be agitated but to a degree less effective and. decreasing as the distance from the region most affected increases. Or, again, since loading a vibrating body lowers its natural period or pitch, if the load be uniformly distributed, the vibration frequency of all its components will be lowered, but if the load be placed at one end of the vibrating body then one of the complications resulting would be a lowering of the natural vibration frequency of that end more than the other. If the tectorial membrane may be considered as a vibrating body with a load gradually increasing till the load carried by its apical end becomes 40 times that of its basal end, then it may at least be assumed that the natural period of its different regions must be lowered as the apical end is approached and sound waves imparted to the endolymph may act upon it accordingly. Several waves, of course, may be transmitted in the same direction simultaneously through a medium.

Results with the model, however, show that sounds of lower vibration frequency throw the entire tectorial membrane into effective vibration.

It may be mentioned that in line with the above a possible suggestion of resonance with the higher sounds was offered by the model. In three cases a note seemed to produce stronger and more evenly continuous vibration of one region of the artificial membrane than in any other of the six regions. For example, the note *a* (220 vibrations per second), while causing vibrations in all regions except region 6, seemed to cause a more definite and more evenly continuous buzz of the signal-marker and telephone at region 4 than in other regions. In region 2, the indication in both signal-marker and telephone was more or less intermittent in contrast, regardless of the amplitude given the note. The note *d*, above *a*, gave the same in region 1, and, less to be expected, the note *g* below *a* gave the same in region 4, the same region as that in which the note *a* gave it. The fact that *a* and *g* gave the evidence in the same region leads to the conclusion that all these suggestions might have been due to lack of uniformity in construction of the model or faults in arrangement of parts. Certainly the model showed no evidence of resonance in the definite way advanced by the theory of Helmholtz as applied to an assumed structure of the basilar membrane. Altogether, with the suggestions so far obtained, the question may be revived as to whether analysis of sound is not accomplished in the interpretations of the stimuli by the central nervous organ. It may be a question whether any actual analysis is accomplished by the cochlea at all other than to such extent as can be possible in the indications that, dependent upon the vibration frequencies and amplitudes of the sound waves applied, varying lengths of the tectorial membrane are thrown into efficient vibration, the lengths beginning at the basal end. Instead of its different regions manifesting selective resonance, the membrane may lie limply passive, agitated by given wave motions only in so far as the resistance offered by itself and the perilymph and endolymph will permit, and, just as in the sense of touch for example, differences in qualities, intensities and frequencies of the stimuli are interpreted by the central nervous system as qualities, intensities and pitch of sounds. A number of different stimuli applied to the unit area of the skin give rise, within the peculiar possibilities of skin innervation, to an interpretation different from one stimulus applied to that area, and stimuli involving varying extents of skin, above certain limits, are interpreted differently. The same may be urged in general for the other sense organs, within the variations of their special differentiation. Gray ('00) in applying a modification of the resonance theory to the basilar membrane, notes, among others, that a mixture of tones of closely approximate vibration frequencies cannot be analysed by the auditory apparatus. If of varying amplitude or intensity, that of the maximum intensity in the mixture alone is perceived. Such a mixture of notes must all involve so nearly the same extent of the vibratory mechanism and hair cells and with so nearly the same frequency of impingement upon the unit area that the different components are not separately interpreted, just as when two or more points applied to the skin close enough together and simultaneously are interpreted as a single stimulus (the sum of the several stimuli), but if one is given greater intensity, that one is appreciated by the brain, while the other images produced by the mixture may be neglected. Impulses mediated by given sense organs are distributed to given areas of the cerebral cortex and differences in the development of certain of these cortical areas are claimed in cases of absence or extraordinary development of the function of the corresponding sense organs. Auerbach ('11) found in his study of the brain of Bernhard Crossman, a famous musician whose specialty was the violincello, that, compared with the average type, the surface of the superior temporal gyrus of both sides was considerably greater than normal, with the middle temporal gryus taking part in the enlargement to a slight extent. With proficient musicians, the chief of the differentiations in the function of the auditory apparatus are the power of analysis and tone memory. The supra-marginal gyrus of Crossmann's brain was described as being also extraordinarily developed. Helmholtz himself concluded that the power of analysis depends largely upon 'attention.'

Whether a note produced vibrations in the artificial tympanic membrane could be easily determined by holding the finger in very delicate contact with the membrane while the note was being sounded. With one of the lower notes used this membrane seemed to manifest a sort of resonance, vibrating with greater excursion than with other notes sounded with approximately the same amplitude. The membrane vibrated apparently as a whole. When the 'ossicle' was removed, its vibrations were even audible. The vibrating diaphragms of the telephone must exercise some form of resonance for it is common experience that certain voices and certain tones are transmitted much more loudly and definitely than others.

(9) With the notes by which the model was capable of being affected, two further phenomena may be mentioned. (1) Occasionally a note would produce a constant buzz in both signal-marker and telephone in one region of the artificial tectorial membrane while in another region the buzzing would manifest

arising and falling in intensity and, more rarely, the result was actually intermittent while the sounding of the note by the horn was continuous. (2) With some of the low notes employed, while a low intensity would result in a continuous buzzing at all regions, if the intensity was greatly increased, certain regions of the membrane seemed to 'buckle' or be lifted away from contact of the platinum wire with the copper plate. Or, in some other cases the current remained made in a region, indicating that the membrane in the region had been forced in closer contact than the adjustment made for a make and break of the current. Ewald and Jäderholm ('06), experimenting with an apparatus producing sounds of known vibration frequency, formulated the conclusion that "all intermittent noises give intermittent tones." This conclusion I think is necessarily correct, but also, could the construction of the model be trusted, the above would suggest that there may be evenly continuous forms of vibration (noises) which can give sensations of intermittent tones. Obviously also the manifestations of rise and fall of intensity or throbs in the buzzing of the telephone suggest the phenomena described as beats and perhaps overtones as well. As is known, the vibrations of the tongue of the organ reed do not give pure tones.

Tinnitus aurium could be produced by a region of the tectorial membrane being so forced down upon the hairs of the hair cells as to remain adherent to them temporarily, or for a long period as sometimes happens, after very violent auditory stimulation. In origin, the tectorial membrane is directly analogous to the otolithic membranes. These latter are normally loaded with calcarious deposits. Under pathological conditions and with advancing age the tectorial membrane may become so loaded, as are other tissues of the body. A light load or a load in a part of the membrane, increasing its inerita, might give rise to 'tone islands' among the higher pitches; a heavier load equally distributed could contribute to the 'falling ears' of old age.

It is not intended here to claim that the tectorial membrane is the only possibly vibratory structure in the cochlea, but, that it is the most adapted in every way and must be the chief vibratory structure contained. In my paper of 1915 attention was called to the fact that the spiral organ (of Corti) or the load carried by the basilar membrane increases appreciably in both width and thickness in passing from the base to the apex of the cochlea. This increase in proportions is, however, by no means so great as is the case with the tectorial membrane. The possibility that wave energy imparted to the fluid in the cochlea may also result in some vibration of the membranous spiral lamina, or basilar membrane, as a whole is not denied. While it is a flat tendon stretched with both edges attached instead of having a free edge and lying limply passive, the fact that it is a little wider at its apical end (averaging 1.4 times) and that its chief load, the spiral organ, increases nearly two times in size in passing to the apical end seem suggestive of an adaptation for vibratory activity. But it must offer greater resistance to undulatory movement than the tectorial membrane, being far less flexible and of different proportions as well as of different structure and position. It is possible that vibrations of low frequency and high amplitude may throw both the tectorial and the basilar membrane into vibration, while the lesser amplitudes may affect the tectorial membrane only. If the two were equally affected by given vibrations, then their undulations would be parallel and, the two remaining the same distance apart, the required stimulation of the hair cells would not occur But, if the position and greater flexibility of the tectorial membrane allow in it vibrations of greater excursion than in the basilar membrane, then the hair cells may be stimulated and with the frequency of the wave motion imparted. It might be advanced that in case of very violent stimulation, the undulation of both membranes is a necessary and economical arrangement, for in such cases injuriously forcible impingement of the tectorial membrane, which alone stimulates the hair cells, may be avoided while yet the tectorial membrane is kept within working distance of the hairs. The increasing load (spiral organ) upon the basilar membrane must act as suggested for that of the tectorial membrane, making it possible, by its increasing resistance with the increasing distance from the basis of the stapes, that varying extents of it may be affected according to the intensity and vibration frequency of the wave energy transferred to the surrounding fluid. In the waves of less amplitude and higher frequencies, vibrations must be reached which are unable to agitate the lamina at all but may agitate the tectorial membrane alone, and then those which agitate decreasing extents of this and with decreasing excursion or amplitudes of vibration up to the functional upper limit of the auditory apparatus.

CONCLUSIONS

Discussion of most of the usually described physiological phenomena of hearing is not undertaken in this paper. It is felt that the model, as compared with the actual auditory apparatus, is so crudely constructed and so gross in size that attempts, based upon its behavior, to explain many of the seemingly complex phenomena would be not only difficult but unprofitable at the present stage of the study. The discussion is confined to the more evident and more probably trustworthy suggestions offered by the behavior of the model:

(1) That the tectorial membrane is a vibratory structure and from its consistency, shape, proportions and position, is the chief vibratory structure in the cochlea.

(2) That it may vibrate in such a way that a modification of the telephone theory of hearing may be applied to it.

(3) That sound waves of low vibration frequency produce vibrations in the entire tectorial membrane regardless of amplitude while those of higher frequency produce vibrations in varying extents of it, depending upon their amplitude.

(4) That among the sound waves of the higher vibration frequencies capable of being appreciated, the extent or length of the tectorial membrane in which efficient vibrations may be induced depends more upon the vibration frequency or pitch than upon the amplitude of the sound waves. The higher frequencies being damped out more readily than the lower, varying extents of the membrane are affected according to the vibration frequencies of the waves applied, the highest frequencies affecting the thin, basal end of the membrane alone.

(5) Some evidences of what may be considered resonance in the tectorial membrane were indicated but were thought question-

ably trustworthy as such. No resonance of the form demanded by the Helmholtz theory is possible. It is suggested that no resonance or analysis of sound is accomplished by the cochlea in itself other than such as may be possible in the evidences that, beginning with its basal end, different extents of the tectorial membrane may be thrown into vibration by different sound waves, depending upon the frequency and amplitude of vibration.

(6) It is admitted that waves of low frequency and high amplitude may induce vibrations also in the less flexible and otherwise less adapted basilar membrane as a whole. Attention is called to the fact that its chief load, the spiral organ, increases in size in passing from the base to the apex of the cochlea and that this suggests a vibratory behavior possible in it similar to but not so comprehensive as that claimed for the tectorial membrane.

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